On-farm biosecurity in livestock production: farmer behaviour, cultural identities and practices of care

Damian Maye[1*] and Kin Wing (Ray) Chan[2]

[1] Countryside and Community Research Institute, University of Gloucestershire, UK (dmaye@glos.ac.uk)

[2] Department of Geography, University of Exeter, UK (K.Chan2@exeter.ac.uk)

* Corresponding author. Tel.: +44-1242-714133; Fax: +44-1242-714395.

Accepted for publication, *Emerging Topics in Life Sciences***, 18.08.2020**

On-farm biosecurity in livestock production: farmer behaviour, cultural identities and practices of care

Abstract

Definitions of biosecurity typically include generalised statements about how biosecurity risks on farms should be managed and contained. However, in reality, on-farm biosecurity practices are uneven and transfer differently between social groups, geographical scales and agricultural commodity chains. This paper reviews social science studies that examine on-farm biosecurity for animal health. We first review behavioural and psychosocial models of individual farmer behaviour / decisions. Behavioural approaches are prominent in biosecurity policy but have limitations because of a focus on individual farmer behaviour and intentions. We then review geographical and rural sociological work that emphasises social and cultural structures, contexts and norms that guide disease behaviour. Socio-cultural approaches have the capacity to extend the more commonly applied behavioural approaches and contribute to the better formulation of biosecurity policy and on-farm practice. This includes strengthening our understanding of 'good farming' constructs, tacit knowledge and farmer influence networks and reformulating biosecurity as localised practices of care. Recognising on-farm biosecurity as practices of biosecure farming care offers a new way of engaging, motivating and encouraging farmers to manage and contain diseases on farm. This is critical given government intentions to devolve biosecurity governance to the farming industry.

Keywords: On-farm biosecurity; Behavioural approaches; Socio-cultural approaches; Good farming; Localised practices of care

1. Introduction

The emergence of infectious diseases of Highly Pathogenic Avian Influenza (HAPI), African Swine Fever and, most recently, Coronavirus (COVID-19) highlight why biosecurity is now a global public health priority. Outbreaks of infectious disease significantly disrupt global trade and exports, and threaten human, livestock and plant life [1,2]. The imperative to 'make life safe' and protect economies from infectious diseases is clear and requires multiple forms and levels of security practice [3]. This includes risk assessment procedures, border controls, transnational systems of standards, international and national protocols, regulations for biosecurity and a raft of guidelines and sanitary practices to transform farmers' and other actors risk behaviours [4,5,6].

Biosecurity is therefore a complex, multi-layered and increasingly problematic term that manifests variously around agriculture and animal disease as forms of discourse, socio-material practice and risk politics. In the UK, the outbreak of Foot and Mouth Disease (FMD) in 2001 was critical in bringing the term 'biosecurity' to the public's attention [7]. At a farm level, biosecurity is a more routine and regulated practice, and in material terms at least is not that novel [8]. FMD and recent zoonotic diseases such as COVID-19 and pandemic avian influenza (H5N1) garner public attention because of their devastating and far-reaching systemic impacts. For livestock farms disease threats are a constant presence and stress to the business of farming, including endemic diseases (e.g. bovine Tuberculosis in the UK), exotic diseases (e.g. FMD, bluetongue in the UK) and production diseases such as lameness and mastitis [9].

This paper reviews on-farm biosecurity for animal health, particularly social science research that examines on-farm biosecurity practices and farmer decision-making. Official definitions of 'biosecurity', including statements about how biosecurity risks should be managed and contained on farms, have a universalising tendency [10]. We see this in the way international and national biosecurity agreements, policies and regimes are presented. However, 'making life safe' is not as straightforward as this. National biosecurity regulations at farm level are more than simply a set of prescriptive practices. Their uptake is often uneven and transfers differently between social groups, geographical scales and agricultural commodity chains [2]. Biosecurity practices at the farm level are also infused with cultural meanings that farmers bring and disease is entangled in the logics and practices that produce food. Farmers have developed ways to manage and sometimes 'live with' biosecurity threats (e.g. bovine Tuberculosis) [11] and these cultural norms and practices may not correspond with how they are interpreted in veterinary epidemiology or animal disease policy. Social science helps to bridge this gap. This paper reviews two main strands of social science work. The first is behavioural and psychosocial models of individual farmer behaviour/decisions, influenced by the Theory of Planned Behaviour

and related frameworks. This approach has gained popular appeal to understand individuals' behaviours. It is the social science approach most commonly applied to formulate biosecurity policy. However, it has notable weaknesses, particularly an overemphasis on individual behaviour, thereby neglecting the wider contexts within which attitudes are formed and behaviours expressed. Geographical and rural sociological work, we argue, addresses this limitation, by emphasising social and cultural structures, contexts and norms that guide disease behaviour. This second strand of work can improve on-farm biosecurity policy formulation by strengthening our understanding of 'good farming' identity, tacit knowledge, farmer knowledge networks and localised practices of care. The latter approach in particular provides a new way of engaging and encouraging farmers to implement on-farm biosecurity as 'practices of care'.

The rest of the paper is structured as follows. First, we summarise what we know, in general terms, about on-farm biosecurity on livestock farms (uptake, common strategies) and review behavioural research that examines the factors that influence the adoption and implementation of animal health practices. This includes critiques of the Theory of Planned Behaviour. Second, we examine socio-cultural approaches to farmer decision-making. This is organised into two sections, which respectively examine cultural meanings of 'good farming' and 'farming scripts' and then reviews research on localised practices of care and farmer knowledge networks.

2. On-farm biosecurity: farmer behaviour and implementation challenges

Biosecurity constitutes a range of practices, from containment controls that restrict movements between infected and non-infected areas, and the management of disease boundaries, to socio-technical interventions, such as testing, the vaccination of wild and farm animals and antibiotic treatments, to practical applications, such as cleansing and disinfecting, to risk management and animal health interventions, such as whole herd health plans. We adopt Shorthall et al's [12] definition of farm biosecurity, as "the set of practices that stop the spread of disease onto or out of an area where farm animals are present". Specific biosecurity practices include: having and utilising a herd health plan; limiting and controlling farm visitors; cleaning and disinfecting vehicles and visitor clothing; limiting contact with neighbours' livestock; reducing contact with wildlife; appropriate disposal of fallen livestock; and sourcing and isolation practices [9, 13, 14]. On-farm biosecurity studies often focus on specific measures or diseases within a sector, such as bovine Tuberculosis, zoonotic diseases, bovine viral diarrhoea or Johne's disease in cattle [15], so care needs to be taken when trying to extrapolate findings to general disease prevention strategies.

The range of specific disease threats and measures vary by sector. However, there is agreement in the literature that levels of uptake of biosecurity measures on livestock farms are low, with a disconnection between industry-recommended biosecurity standards and farmer practices. Farmers

report having a high concern for disease threats but this concern does not translate into on-farm biosecurity practices [26], either at all or in ways that meet industry expectations [7]. Brennan and Christley's [9] study of cattle farmers, for example, found that many producers did not implement biosecurity practices even though they felt they were cost-effective and time-efficient. A comparative analysis of sheep and pig farmers in England by Garforth et al. [14] reported similar findings, with farmers understanding disease risk and practices to reduce disease risk, but not always implementing those practices [14]. There are studies too of specific mechanisms that may influence behaviour. Compensation, for example, may encourage keepers to report disease quickly and adhere to legal requirements regarding biosecurity. Studies suggest compensation may not provide a strong incentive for animal keepers to implement biosecurity measures to reduce the risk of disease spread [16]. Analysis of exotic livestock disease management behaviour found that the majority of keepers across sectors (poultry, sheep, cattle, pigs, equine, backyard/hobby farm, and non-food) were generally unware of the current compensation schemes systems beyond the vague existence of some form of recompense [17].

Behaviour change models, particularly the Theory of Planned Behaviour, have been widely applied in animal health to identify farmers' biosecurity attitudes and behaviours. Fishbein and Ajzen [18] first proposed the Theory of Reasoned Action in the 1970s, as a conceptual model to examine the links between belief and behaviours, followed by the Theory of Planned Behaviour (TBP) and more recently the Reasoned Action Approach [19]. The key theoretical concern of TBP is to understand how psychological factors (i.e. perceptions, individual values and beliefs) influence, in this case, farmers' biosecurity practices. According to Ajzen [20], there are three major factors that influence farmers' intentions to perform or not farm biosecurity: (1) farmers' *personal attitudes* influence behaviour based on their evaluation of favourable and unfavourable elements; (2) perceived social pressure may influence the *subjective norms* of farmers to perform or not behaviours; and (3) farmers' *perceived control*, which is their capability to perform behaviours.

TBP has been widely applied in animal health studies to examine the relationships between farmers' biosecurity attitudes and behaviours. Garforth el al. [14], see figure 1, for example, employ the TBP to explore sheep and pig farmers' perceptions of disease risks, attitudes toward biosecurity practices and the availability of biosecurity knowledge and previous experiences. Their model combines ideas from TBP with the Theory of Reasoned Action and the Health Belief Model. Farmers' disease management behaviour is influenced by (see figure 1): their knowledge of specific

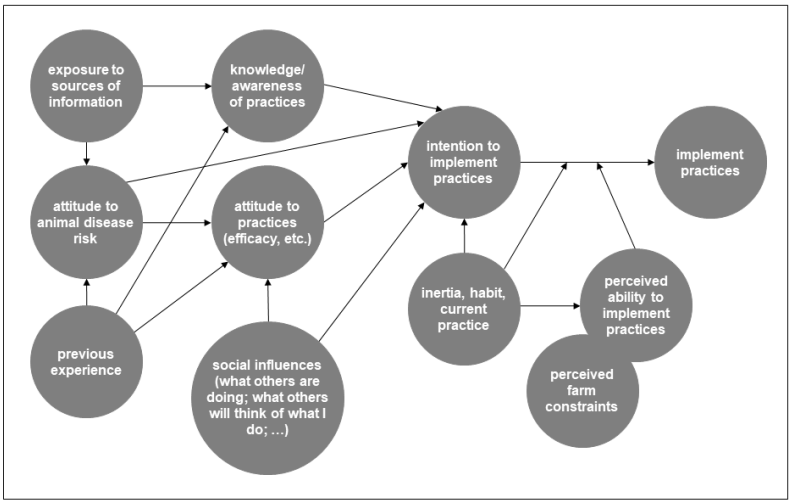

Figure 1 Behavioural framework to identify factors that influence farmers' disease risk management decision-making [Adapted from 14, p.459]

practices; their attitudes to specific practices and disease risk management generally; their view of the efficacy of practices to reduce disease risk; previous experience of specific practices, including that heard from others; their perception of their ability to put specific practices into effect and their perception of factors that constrain their ability to put specific factors into effect ('perceived behavioural control'); their perception of what other famers in similar situations are doing; and their perception of what other people important to them would think about them adopting the measures ('subjective norms') (*ibid.*, p. 457, p. 459). For the pig sector, Kauppinen et al. [21] examine how stockmanship has a major influence on pig farmers' animal welfare and productivity; while de Lauwere et al. [22] understand how pig farmers' choice who has and has not changed to group housing for pregnant sows with regard to animal welfare. For the cattle sector, TBP is used to examine the attitudes and intentions of dairy farmers, including what drives and hinders farmers to take action to improve dairy cow foot health [23].

Increasingly behavioural approaches are combining TBP with other approaches. Richens et al. [15], for example, examine attitudinal and behavioural data from 757 dairy cattle farms in Great Britain, combining TPB with a trans-theoretical model of behaviour change, the idea being that barriers to behaviour change are stage and context specific, which means interventions are much better if they are tailored to reflect a farmer's current stage of change, categorised as 'inaction' (no intention to change within 6 months, thinking about changing in the next 6 months, and thinking about changing in the next month) and 'action' (changed within the last 6 months and changed over 6 months ago). This is useful because it shows that large one-size-fits-all interventions targeted at large groups of farmers may not result in significant behaviour change. Two groups of farmers were identified in their study: those who reported not applying biosecurity measures with no intention to do so in the future and those who reported implementing

biosecurity for some time. More farmers also agreed with statements relating to their ability to control rather than prevent disease.

In an important paper, Burton [24] reflects critically on the TPB approach and argues that commentators in TPB tend to over-emphasise the "attitude" factor as the main determinant of behaviour and over-depend on using psychometric scaling techniques (i.e. Likert-type scaling) and actor-oriented quantitative methodologies to understand the attitudes of individual farmers. This neglects other social and cultural factors that shape farmers' decision-making. In particular, this involves understanding how 'symbolic values' influence farmers' biosecurity decision making through relations with the farming community, farmers' personal identity and family history. This is important to unravel how symbolic values produce 'good farming' identity and generate place-specific biosecurity skills, knowledge and culture [25].

One important conclusion regarding uptake of biosecurity measures is the suggestion that livestock producers often feel they are doing all that they reasonably can to minimise disease risk, with practices not implemented on farm because they are deemed not relevant or ineffective [14, p.456]. Higgins et al. [26, pp. 22-23] identify two types of challenge which explain why producers adopt this stance. The first is *farm-level* and linked to factors such as physical and economic constraint, farmer socio-demographics and access to information. The second is *institutional*, including a lack of trust between farmers and governing authorities and because farmers attribute responsibility for biosecurity to government, even though farmers at the same time question the capacity of governments to manage biosecurity threats. This emphasises the importance of the local level, as the frontline of disease outbreaks and the critical scale to best understand disease networks (as combinations of material and human connection).

3. Socio-cultural analysis of biosecure practices: local contexts and 'good farming' identities

Biosecurity research within geography and rural sociology is using socio-cultural approaches to understand farmers' biosecurity decision-making, including how farmers' responsibility is linked to understandings of nature and their farm, good farming identities, social scripting and access to resources.

Biosecurity meanings at the local level

A focus on farmers' understanding of biosecurity at the local level is important given that they are the key delivery mechanisms of biosecurity techniques. Disease management as it occurs at farm level appears to be a more personal and multi-faceted undertaking, closely linked to the 'craft work' of animal husbandry [27]. Biosecurity meanings at the local level are complex, tacit and

highly nuanced and research shows how they are addressed within the wider context of managing a local micro ecosystem. This is more than understanding biosecurity as a set of measures to keep disease out of farming systems. This approach to disease management is relational and involves working across numerous locations and species. For example, Hinchliffe et al. [28, p.6] propose a 'Pathological lives' approach to understand how specific configurations and assemblages of farmers, farm animals, microbes, infrastructures and ways of governing on-farm diseases make specific diseases happen. Ward and Enticott [29] further develop this relational thinking to understand how animal disease is enacted in particular situations through materials (i.e. record keeping, maps, graphs, policy documents) and particular actants (i.e. government officials, veterinarians, animals and farmers). For instance, smallholders' biosecurity situations are constructed in specific animal-human relationships, knowledge practices and social-political pressures, which engender farmers' responsibility and care towards their animals [30].

These relationships are full of complexity and heterogeneity because different social and cultural symbols (e.g. trust, relationships with government officials, stockmanship) and farm materials (e.g. technological systems, infrastructure, waste treatment facilities) influence farmers' decision-making regarding biosecurity behaviours [25, 31, 32, 33]. Fatalism and luck also play a part. In cases of endemic animal health, for example, if farmers do not see evidence of improvement they become fatalistic, adopt old habits and have 'candidates' (ideal types of farm, cows, wildlife) for disease breakdowns, which often perpetuate established cultural beliefs [31]. These are forms of 'farming script', a type of 'social scripting' that shape farmers' on-farm biosecurity practices. "Social scripting" is a process where persons are subconsciously and consciously conditioned to follow rules, and adapt values and behavioural patterns determined by society, its subculture, or some ethic or socioeconomic group [34, p. 144]. Social scripts are a mental map and once internalised influence farmers' values and behaviour. Enticott and Vanclay [35] and Vanclay and Enticott [36], for example, examine how 'animal health scripts' circulate in farming communities. Animal health scripts are "moral resources" used by farmers to account for their behaviour in relation to animal disease and contribute to the ongoing construction of identity.

In addition to the practical and tacit nature of biosecurity, farmers' understandings of biosecurity are also linked to narratives, beliefs and philosophies of nature [37]. These approaches to biosecurity and nature are not easily challenged by abstract understandings generated, for example, through science or risk communication. Research on badger vaccination, for example, shows how farmers think about biosecurity interventions and their efficacy in culturally sensitive ways relative to understandings of nature and farm animals [11]. Two narratives of nature emerged – a 'balance of nature' narrative and a ''clean' and 'dirty' badgers' narrative. These cultural

understandings of nature explain why farmers have preference for certain wildlife control methods over others, but they are not always compatible and reveal the challenges to be negotiated in new styles of partnership-based animal health governance. Findings from a longitudinal study of the same badger vaccination trial found that vaccine confidence levels were low to start with but declined further by the end of the project [38]. This was linked to two factors: first, a failure to implement a more inclusive and collaborative approach to disease control in which farmers were actively engaged in planning vaccination (the 'seeing is believing' mechanism); and second, a failure to understand farmers' contextual familiarity with farm animal vaccines and their cultural relevance (the 'practice similarity' mechanism). For example, farmers' compared their whole herd approach to vaccination (or disease testing) and the suggestion that not all badgers would need to be vaccinated because of the herd immunity concept. The failure to trigger either mechanism points to the need for policy to develop more supportive socio-cultural contexts.

Good farming and biosecurity

A small number of studies have used the 'good farming' concept to examine how biosecurity policies construct the identity of good farmers and develop farmers' biosecurity practices [12,13, 26]. Social and cultural influences play a crucial role in shaping farmers' decision-making and biosecurity practices. This involves understanding how socio-cultural factors produce "good farmers' practices" which transform farming practices and standards. An important insight from this work is that "farmers will strive to be good farmers according to the rules of the game and accumulate different kinds of capital within the field of agriculture" [12, p.586].

In practical terms, 'good farming' is expressed through forms of productivity, cleanliness, good record keeping and symbolic values in the eyes of other farmers [29, 33, 39]. Biosecurity practices such as following animal health standards, farm assurance schemes and codes of practices are symbols of 'good farming'. Previous studies have also identified good on-farm biosecurity practices as achieving high husbandry productivity with a clean environment, developing knowledge on the local environment and geographies around their farms, the production of healthy animals and better manure management [32, 40, 38]. Farmers may adopt their behaviours to attain good farming identity, approval and social recognition from other farmers [12, 41]. Early research on good farming suggested farmers were resistant to change and cultural capital (the actions that symbolise good farming) created inertia, but new research is arguing good farming standards do change, especially if challenged economically (the so-called 'taste of necessity').

In 'good farming biosecurity' work, 'cultural capital' is expressed in two ways: good stock keeping skills and healthy and profitable animals. A study of good farming identities and the control

of exotic livestock diseases in England highlighted three good farmer ideals [13]:

- *the 'Good Stockman' identity* – this is about stock keeping skills and care for animals, often described as 'innate, tacit knowledge', especially among cattle and sheep farmers;
- *the 'Good Neighbouring Farmer identity* – this is about being and being seen as a good neighbour by not causing biosecurity problems for local farms (e.g. careful when buying animals, culling and reporting sick animals that pose a risk to other farms); and
- *the 'Good Public Facing Farmer' identity* – this is the farmer who has a good reputation for biosecurity. Animal keepers expressed a responsibility to the industry to convey good disease control practices, in exotic disease outbreaks, particularly for their livestock sector.

Naylor et al's [13] study suggests that understandings of 'good farming biosecurity' are different for different livestock sectors. For pig and poultry systems, good farming is symbolised through monitoring key performance indicators (particularly mortality rates and water intake); cattle and sheep farmers refer to tacit skills that allow farmers to determine animal health by eye. Animal keepers defined themselves as a certain 'type' of animal keeper, making distinctions between themselves and others, particularly between 'commercial' (or 'proper') farmers and 'hobby' farmers [30], reflecting the wider productionist good farming logic described in early literature. Animal keeper practices are influenced by their individual identity as a good farmer but also by their collective identities within the sector and with those outside [13, p.16].

4. Practices of biosecure farming care and farmers' influence networks

Caring for animals' health is a key part of 'good farmer' identity [12, p.584]. This highlights an inconsistency with attitudinal studies, which report biosecurity uptake as generally low. Recent social science work is using ideas from care, to show how at a localised level, farmers may be managing disease risk in ways that they perceive as 'good' but which are not formally recognised as good biosecurity practice. Higgins et al. [26], for example, examine biosecurity practices on commercial beef farms in New South Wales and Queensland, Australia. Their research draws on a much larger corpus of social science work related to care (see Mol [42] for example). They argue that biosecurity on farms is implemented through two types of care practices: firstly, practices that *hold together* different elements and objects of care to enable healthy farm animals and a profitable farm enterprise; and secondly, practices that keep disease risks *separate* from on-farm care work. This analysis shows the *skilled craftwork* that farmers employ to hold together different elements of care and, using what they term *'fluid engineering'*, the efforts farmers go to create barriers that separate on-farm practices of care from off-farm disease risks. In practical terms, craftwork includes the embodied skills, tacit knowledge and practical judgement that cattle farmers use to maintain good herd health (e.g. regularly observing and monitoring their cattle for signs of disease, the skills

involved to get to know one's animals, vaccination and herd health plans as important material devices). Fluid engineering on farms involves two key practices: selective or no buying in of cattle, often combined with isolation of new stock on arrival, and the use of physical barriers, such as fencing and restricted entrance points to the farm. Producers recognised complete freedom from disease was not possible.

Centralised approaches to biosecurity, which standardise disease risk management, including population-level risk communication models, are about getting farmers to align with national recommended practices. Localised practices of biosecure care [26, p.15] suggests that farmers may be more engaged in biosecurity practices than previously reported, if biosecurity principles are interpreted more in terms of producers' strategies to care for their animals. This supports other social science findings, which note the importance of embodied skills and localised knowledge practices as a way to engage farmers in biosecurity practices [27]. This alters the language away from barriers to biosecurity adoption and implementation to biosecure care practices. Understanding localised practices of care is a key to understand on-farm biosecurity. There are multiple forms of localised practices of care to enable farmers to keep their animals healthy across different sectors and localities (see Table 1). Cattle farmers utilise their stockmanship skills, resources (e.g. farm buildings, protocols) and develop rapport with their vets, neighbours and other farmers to show their awareness of care towards their cattle. Pig farmers deploy material (e.g. muck, vaccines) and non-material (e.g. good farming identity, personal relationships) approaches to calibrate the most appropriate form of care to fit their farm situation. For poultry farmers, using high-tech technology and raising sentinel chicken (unvaccinated chicken) are ways to confirm the presence of disease. These examples echo Higgins et al's[26] and Enticott's[31] appeal to contextualise the diversity of localised practices of care. This is crucial for governing institutions to engage with farmers more effectively in managing animal disease.This is important given efforts to devolve responsibility for biosecurity from the government to the farming industry and farmers [12, 26] with a particular emphasis on relations between the vet and the farmer.

A number of papers reviewed identify the role of influencers to farmer behaviour. Theory of Planned Behaviour work, for example, suggests farmers are more likely to be influenced by 'in group' members [13, p.15], with analysis showing that the vet is a primary source of information and advice in relation to animal health [14]. Papers on 'good farming' and 'practices of care' also recognise the role of the local vet as a key source of expertise [12, 26, p.28]. A study of control measures for bovine Tuberculosis, for example, showed that different stakeholders become important for different measures [43]. Vets were important, but in scenarios where the farmer was

Table 1 Biosecurity as localised practices of care: cattle, pigs and poultry

Livestock sector	Biosecurity as localised practices of care	Country/Region	References
Cattle	• Set protocols to prevent disease. • Equip farmers and workers with good observational skills to identify sick animals. • Keep a closed herd. • Maintain close relationships with vets, neighbours and other farmers.	United Kingdom	Shorthall et al. [12]
	• Good maintenance of farm buildings and working relationships among workers to generate good 'cowshed culture'. • Promote positive farming practices and attitudes to improve animal welfare.	New Zealand	Burton et al. [44]
	• Provide formal rewarding systems, less hierarchical management systems and hire non-kin employees to improve farm workers' responsibilities and self-esteem to care for animals.	Ireland	McAloon et al.[45]
Pig	• Manage pigs' immunity through: (1) vaccination and (2) introducing muck from the recipient herd to gradually acclimatise pigs to disease pressures. • Maintain good husbandry skills (e.g. good airflow, welfare and stress management).	United Kingdom	Hinchliffe and Ward [27]
	• Good manure management and maintaining a tidy farm. • Capable to develop good relationships (i.e. Guanxi) with government officials. • Acquire high 'personal quality' (i.e. Suzhi) in the eyes of other farmers.	China	Chan and Enticott [32]
	• Make happy pigs by keeping pigs outside and free range. • Being reflexive on pig-human relationships and the health and welfare of their pigs.	Sweden	Saunders [41]
Poultry	• Monitor the weight, water intake and food conversion graph of flocks. • Show care, build rapport with workers and create mutual responsibility to maintain high biosecurity practices.	United Kingdom	Naylor et al. [13]
	• Purposefully raise sentinel chicken (unvaccinated chicken) at the end of the rows of cages to show early signs of avian influenza. The stocking rate is 60 sentinels for a flock of 3,500 broilers.	Hong Kong, SAR	Keck [46]
	• Farmers show high levels of responsibility and moral commitment to their community. This motivates farmers to care for their flocks and self-regulate their practices to monitor bird-flu.	Vietnam	Porter [47]

less familiar with the disease control measure, other stakeholders also became important, including the government. In other words, influential stakeholders on farms can differ, often depending on how familiar farmers are with the control measure. Industry partners who are important to farmers in relation to biosecurity (e.g. vet, milk buyer) can make use of this information, identifying and engaging with these stakeholders to improve the likelihood of uptake. Research also identifies the need for stage-matched interventions, to get farms from pre-action to action stages. This shows that while farmers like to speak to their vets, they perceive vets as less likely to be concerned about whether farmers actually undertake biosecurity, indicating there is still work to do in terms of communication strategies between farmers and vets [15, pp68-69].

5. Conclusion

This paper has reviewed two main bodies of social science work to inform an individuals' biosecurity decision making at the farm-level: the behavioural approach and the sociocultural approach. Behavioural approaches are prominent in biosecurity policy but, as we have shown, these models have limitations because of a focus on individual farmer behaviour. Socio-cultural approaches provide an important and undervalued complement to this work, strengthening our understanding of 'good farming' identity, tacit knowledge, farmer influence networks and localised practices of care. Government intentions are pointing increasingly towards devolving biosecurity responsibility to farmers and the farming industry. Better understanding of local-level context, farmers' social identities, practices of care and networks of influence provides useful additional policy learning tools and ways to engage, motivate and encourage farmers in biosecurity. This means accommodating situated forms of knowledge and adapting stakeholders assigned to deliver specific biosecurity messages. Scripts can be built into policymakers' attempts to convince farmers of the need to improve biosecurity. This includes greater appreciation of how wider care practices (e.g. producers' herd health practices) align with biosecure care and better recognition of how farmers care for their animals and the viability of farming enterprises. As we move towards devolved, or more accurately, mutual forms of devolved responsibility, practices of care are a critical part of this co-produced identity between the farmer and state. Re-framing on-farm biosecurity as care thus 'becomes less about producers complying with specific measures and procedures, and more about governing authorities nurturing producers' care practices of skilled craftwork and fluid engineering' [26., p. 37].

Summary Points

- Reviews social science animal health research, including on-farm biosecurity practices and farmer decision-making.
- Identifies two main forms of social science work: behavioural and psychosocial models of individual farmer behaviour and socio-cultural approaches that emphasise social and cultural structures, contexts and norms.
- Behavioural approaches are prominent in biosecurity policy but have limitations because of a focus on individual farmer behaviour and intentions.
- Socio-cultural approaches strengthen our understanding of 'good farming' identity, farmer knowledge networks and practices of biosecure care.
- Reframing biosecurity as practices of biosecure farming care can help policy stakeholders to engage and motivate farmers to manage and contain disease on their farms.

Acknowledgements

We are grateful to two anonymous reviewers for their constructive comments on an earlier version of this paper. The usual disclaimers apply.

Author contribution statement

D.M. and R.C. wrote the manuscript. D.M. adapted Figure 1.

Competing interests

There are no competing interests.

References

1 Maye, D., Dibden, J., Higgins, V., & Potter, C. (2012). Governing biosecurity in a neoliberal world: comparative perspectives from Australia and the United Kingdom. *Environment and Planning A*, *44*(1), 150-168.

2 Hinchliffe, S., Allen, J., Lavau, S., Bingham, N., & Carter, S. (2013). Biosecurity and the topologies of infected life: from borderlines to borderlands. *Transactions of the Institute of British Geographers*, *38*(4), 531-543.

3 Hinchliffe, S., & Bingham, N. (2008). Securing life: the emerging practices of biosecurity. *Environment and Planning A*, *40*(7), 1534 -1551.

4 Wilkinson, K., Grant, W. P., Green, L. E., Hunter, S., Jeger, M. J., Lowe, P., ... & Waage, J. (2011). Infectious diseases of animals and plants: an interdisciplinary approach.

5 Wakefield, S., & Braun, B. (2014). Governing the resilient city. *Environment and Planning D: Society and Space*, *32*(1), 4-11.

6 Maye, D. and Chan K. W. (2020). Contrasting national biosecurity regimes: plant and animal bio-politics in the UK and China. In Fall, J., Francis, R., Schlaepfer, M.A. and Barker, K. (Eds.) The Routledge Handbook of Biosecurity and Invasive Species. Routledge, Abingdon.

7 Enticott, G. (2014). Biosecurity and the bioeconomy: The case of disease regulation in the UK and New Zealand. *Researching sustainable food: Building the new sustainability paradigm. London: Earthscan*, 122-142.

8 Donaldson, A. (2008). Biosecurity after the event: risk politics and animal disease. *Environment and Planning A*, *40*(7), 1552-1567.

9 Brennan, M. L., & Christley, R. M. (2013). Cattle producers' perceptions of biosecurity. *BMC veterinary research*, *9*(1), 71.

10 Law, J. (2006). Disaster in agriculture: or foot and mouth mobilities. *Environment and planning A*, *38*(2), 227-239.

11 Maye, D., Enticott, G., Naylor, R., Ilbery, B., & Kirwan, J. (2014). Animal disease and narratives of nature: Farmers' reactions to the neoliberal governance of bovine Tuberculosis. *Journal of Rural Studies*, *36*, 401-410.

12 Shortall, O., Sutherland, L. A., Ruston, A., & Kaler, J. (2018). True cowmen and commercial farmers: exploring vets' and dairy farmers' contrasting views of 'good farming' in relation to biosecurity. *Sociologia Ruralis*, *58*(3), 583-603.

13 Naylor, R., Hamilton-Webb, A., Little, R., & Maye, D. (2018). The 'good farmer': farmer identities and the control of exotic livestock disease in England. *Sociologia Ruralis*, *58*(1), 3-19.

14 Garforth, C. J., Bailey, A. P., & Tranter, R. B. (2013). Farmers' attitudes to disease risk management in England: a comparative analysis of sheep and pig farmers. *Preventive veterinary medicine*, *110*(3-4), 456-466.

15 Richens, I., Houdmont, J., Wapenaar, W., Shortall, O., Kaler, J., O'Connor, H., & Brennan, M. L. (2018). Application of multiple behaviour change models to identify determinants of farmers' biosecurity attitudes and behaviours. *Preventive veterinary medicine*, *155*, 61-74.

16 Enticott, G., & Lee, R. (2015). Buying Biosecurity: UK compensation for animal diseases. In *The Changing Landscape of Food Governance*. Edward Elgar Publishing.

17 Hambilton-Webb, A., Naylor, R., Little, R., & Maye, D. (2016). Compensation and exotic livestock disease management: the views of animal keepers and veterinarians in England. *Veterinary Record*, *179*(20), 513.

18 Fishbein, M., & Ajzen, I. (1975). Belief, attitude, intention and behavior. An introduction to theory and research. Reading, MA: Addison-Wesley Publishing Company.

19 Fishbein, M., & Ajzen, I. (2011). *Predicting and changing behavior: The reasoned action approach*. Taylor & Francis.

20 Ajzen, I. (1991). The theory of planned behavior. *Organizational behavior and human decision processes*, *50*(2), 179-211.

21 Kauppinen, T. (2013). Farm animal welfare and production in relation to farmer attitudes.

22 de Lauwere, C., van Asseldonk, M., van't Riet, J., de Hoop, J., & ten Pierick, E. (2012). Understanding farmers' decisions with regard to animal welfare: The case of changing to group housing for pregnant sows. *Livestock Science*, *143*(2-3), 151-161.

23 Bruijnis, M. R. N., Hogeveen, H., & Stassen, E. N. (2013). Measures to improve dairy cow foot health: consequences for farmer income and dairy cow welfare. *Animal*, *7*(1), 167-175.

24 Burton, R. J. (2004). Reconceptualising the 'behavioural approach' in agricultural studies: a socio-psychological perspective. *Journal of Rural studies*, *20*(3), 359-371.

25 Burton, R. J. (2004). Seeing through the 'good farmer's' eyes: towards developing an understanding of the social symbolic value of 'productivist'behaviour. *Sociologia ruralis*, *44*(2), 195-215.

26 Higgins, V., Bryant, M., Hernández-Jover, M., Rast, L., & McShane, C. (2018). Devolved responsibility and on-farm biosecurity: practices of biosecure farming care in livestock production. *Sociologia Ruralis*, *58*(1), 20-39.

27 Hinchliffe, S., & Ward, K. J. (2014). Geographies of folded life: How immunity reframes biosecurity. *Geoforum*, *53*, 136-144.

28 Hinchliffe, S., Bingham, N., Allen, J., & Carter, S. (2016). *Pathological lives: disease, space and biopolitics*. John Wiley & Sons.

29 Enticott, G., & Ward, K. (2020). Mapping careful epidemiology: Spatialities, materialities, and subjectivities in the management of animal disease. *The Geographical Journal*.

30 Holloway, L. (2019). Smallholder knowledge-practices and smallholding animals: Threats or alternatives to agricultural biosecurity?. *Journal of rural studies*, *69*, 19-29.

31 Enticott, G. (2008). The spaces of biosecurity: prescribing and negotiating solutions to bovine tuberculosis. *Environment and Planning A*, *40*(7), 1568-1582.

32 Chan, K. W. R., & Enticott, G. (2019). The Suzhi farmer: Constructing and contesting farming Subjectivities in post-Socialist China. *Journal of rural studies*, *67*, 69-78.

33 Chan, K. W. (2020). Politics of smell: Constructing animal waste governmentality and good farming subjectivities in colonial Hong Kong. *Environment and Planning C: Politics and Space*, 2399654420914320.

34 Silvasti, T. (2003). The cultural model of "the good farmer" and the environmental question in Finland. *Agriculture and human values*, *20*(2), 143-150.

35 Enticott, G., & Vanclay, F. (2011). Scripts, animal health and biosecurity: The moral accountability of farmers' talk about animal health risks. *Health, Risk & Society*, *13*(4), 293-309.

36 Vanclay, F., & Enticott, G. (2011). The role and functioning of cultural scripts in farming and agriculture. *Sociologia Ruralis*, *51*(3), 256-271.

37 Buller, H. (2008). Safe from the wolf: biosecurity, biodiversity, and competing philosophies of nature. *Environment and Planning A*, *40*(7), 1583-1597.

38 Maye, D., Enticott, G., & Naylor, R. (2020). Theories of change in rural policy evaluation. *Sociologia Ruralis*, *60*(1), 198-221.

39 Escobar, M. P., & Demeritt, D. (2017). Paperwork and the decoupling of audit and animal welfare: The challenges of materiality for better regulation. *Environment and Planning C: Politics and Space*, *35*(1), 169-190.

40 Hinchliffe, S., & Blowers, A. (2003). Environmental responses: radioactive risks and uncertainty. *Environmental responses*, 7-49.

41 Saunders, F. P. (2016). Complex Shades of Green: Gradually Changing Notions of the 'Good Farmer'in a S wedish Context. *Sociologia Ruralis*, *56*(3), 391-407.

42 Mol, A. (2008). *The logic of care: Health and the problem of patient choice*. Routledge.

43 Maye, D., Enticott, G., & Naylor, R. (2017). Using scenario-based influence mapping to examine farmers' biosecurity behaviour. *Land use policy*, *66*, 265-277.

44 Burton, R. J., Peoples, S., & Cooper, M. H. (2012). Building 'cowshed cultures': A cultural perspective on the promotion of stockmanship and animal welfare on dairy farms. *Journal of Rural Studies*, *28*(2), 174-187.

45 McAloon, C. G., Macken-Walsh, Á., Moran, L., Whyte, P., More, S. J., O'Grady, L., & Doherty, M. L. (2017). Johne's disease in the eyes of Irish cattle farmers: a qualitative narrative research approach to understanding implications for disease management. *Preventive veterinary medicine*, *141*, 7-13.

46 Keck, F. (2020). *Avian Reservoirs: Virus Hunters and Birdwatchers in Chinese Sentinel Posts*. Duke University Press.

47 Porter, N. (2016). One Health, Many Species: Towards a multispecies investigation of bird flu. In *Humans, Animals and Biopolitics* (pp. 138-153). Routledge.