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RESEARCH ARTICLE

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Evaluation of 'ClassyFarm', the Italian integrated surveillance system of livestock farms, in the context of antimicrobial use and antimicrobial resistance

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ABSTRACT

ClassyFarm is an integrated surveillance system for monitoring the Italian livestock farms on risks related to antimicrobial use (AMU) and resistance (AMR) and other indicators, such as animal welfare and farm biosecurity. In the framework of the CoEvalAMR network we evaluated ClassyFarm by using three evaluation tools: the OH-EpiCap, the FAO PMP-AMR and the NEOH evaluation tool. Evaluation was performed by interviewing representatives of ClassyFarm, National Health System veterinarians, farm vets, farmers, livestock industry entrepreneurs, academy experts in AMR/AMU. NEOH and PMP-AMR evaluation tools were applied twice (at 2 years interval) to detect changes in the implementation of the system over time, while OH-EpiCap was applied once. The three tools differ in evaluation objectives, depth of analysis, and time/training resources needed to perform the evaluation. However, each of them enables to gather different information, which can serve as a basis for the discussion of possible adaptations/improvements of ClassyFarm. Even though ClassyFarm has a limited degree of One Health (OH) implementation, the evaluation showed that the system has evolved from a barely biosecurity and welfare surveillance system towards a more integrated OH approach. A transdisciplinary nature is also emerging, with the involvement of the environmental sector. However, there is space for improvement in resource allocation, data sharing and communication. Beyond the structural evaluation, surveillance systems should be evaluated also in relation to cost-effectiveness and system impacts.

HIGHLIGHTS

- Evaluation of surveillance systems is useful to detect gaps and improve the systems' effectiveness
- The evaluation of the ClassyFarm system showed that there is space for improvement in resource allocation, data sharing and communication
- Significant improvements have taken place regarding AMU/AMR awareness and AMU reduction in Italy, although it is difficult to assess the direct impact of ClassyFarm on these changes.

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AMU/AMR; livestock farms; surveillance; evaluation; One Health

Introduction

Antimicrobial resistance (AMR) is the ability of microorganisms to persist or grow in the presence of drugs designed to inhibit or kill them. Although it is a natural process, overuse and misuse of antimicrobials are drivers of AMR insurgence and spread (OECD 2022). In particular, the livestock sector is the largest consumer of antimicrobials globally (Tiseo et al. 2020; Schar et al. 2021; Ardakani et al. 2024). Because of AMR, antimicrobials loose effectiveness, and many infections are becoming increasingly difficult or impossible to treat for both human and veterinary medicine. Furthermore, AMR microorganisms and genes can spread from animals to humans and vice versa, and through the environment (Ardakani et al. 2023). For this reason, AMR represents a global health challenge

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that needs an integrated One Health (OH) approach (WHO 2015; Larsson and Flach 2022).

Worldwide, AMR is a serious threat and calls for concerted efforts at local and national levels (OECD 2022). In Italy, monitoring and surveillance of AMR is considered a national strategic pillar and is part of the Italian integrated plan to fight AMR ('PNCAR'; Italian Ministry of Health 2022) that, among its objectives, includes the reduction of antimicrobial use (AMU) in farmed animals. The current PNCAR (2022–2025) has a broader approach as compared to the previous (first) PNCAR (2017–2020), since it encompasses environmental health besides animal and human health. Moreover, the Italian Ministry of Health – through the Directorate General of Animal Health and Veterinary Drugs – has developed ClassyFarm (ClassyFarm 2023; https://www.classyfarm.it/index.php/en/), an integrated surveillance system for monitoring and characterising livestock farms according to risk. The main areas of interest of ClassyFarm are animal welfare, farm biosecurity, slaughterhouse data and antimicrobials (AMU and AMR). The system evaluates farms' performance and can highlight best practices as regards biosecurity, management, and farm structure (Ventura et al. 2021; Holighaus et al. 2023), addressing possible interventions for improving animal production, preventing animal diseases and contrasting AMR spread. ClassyFarm can process, integrate and analyse data from different sources, and it is intended for public and private stakeholders (ClassyFarm 2023). The development of ClassyFarm is still ongoing, however, the PNCAR already uses it for monitoring AMU in farms and for veterinary pharmaco-surveillance. Recently, the Italian Ministry of Agriculture decided to use the ClassyFarm indicators to evaluate farm compliance with animal welfare and AMU standards required for the direct payments delivered to farms under the 2023–2027 EU's Common Agricultural Policy (CAP).

Within the activities of the international network CoEvalAMR (Convergence in evaluation frameworks for integrated surveillance of AMU and AMR; https://guidance.fp7-risksur.eu/), aimed at developing guidance for the evaluation of integrated surveillance for AMU and AMR, we evaluated ClassyFarm applying three evaluation tools, to assess and characterise the surveillance capabilities of ClassyFarm as regards AMU and AMR.

Our aim was to evaluate the different aspects of the surveillance system that could be better intercepted by each of the three evaluation tools. In particular, we focused on the components that could be further improved to increase the integrated nature of the surveillance system.

Materials and methods

Context and description of the system and health initiative

The evaluation of ClassyFarm according to a OH approach requires the preliminary understanding of its role and functioning in the wider legislative and institutional context in which it operates. ClassyFarm is a unit with specific mission and strategy, i.e. providing information to public and private stakeholders by collecting new data and processing existing information, to favour decision making at different level of operation (production, technical advising, and public health management). We first examined ClassyFarm as a processing unit, i.e. an institution or organisation which allocates resources to comply its mission, which is processing and delivering information. This approach stems from typical, well-rooted techno-economic and firm organisation concepts, which allow for the description of a production process. Secondly, we applied the systems thinking approach to depict the role of ClassyFarm according to a cross-sectoral vision. Systems thinking applied to health-related studies refers to a conceptual framework, which considers the knowledge generated from studying complex systems in multiple disciplines and includes all components that impact health and their dynamic interactions over time (Swanson et al. 2012; Chughtai and Blanchet 2017). Internal expert discussion and the current available knowledge (including former and current experience of members of the CoEvalAMR network) supported our system thinking exercise, which lead to the representation of the role of ClassyFarm in a larger framework, as shown in Figure 1.

The first version of the ClassyFarm system was made available to some public (national and local veterinary public health managers) and private stakeholders (farm veterinarians) in December 2017, as an initiative of the Directorate General of Animal Health and Veterinary Drugs of the Italian Ministry of Health. The system underwent several updates and, in its current version, is also available to other stakeholders such as farmers, certification authorities, companies and supply chain managers. ClassyFarm is the result of various projects funded by the Italian Ministry of Health. It was developed by the Istituto Zooprofilattico Sperimentale della Lombardia e dell'Emilia Romagna (IZSLER), belonging to the Italian network of public laboratories for veterinary health and epidemiology, in collaboration with the University of Parma and other public (national and local authorities, universities, etc.) and private subjects (veterinarians, farmers, livestock companies, etc.). The system processes data on AMU, farm biosecurity, animal health

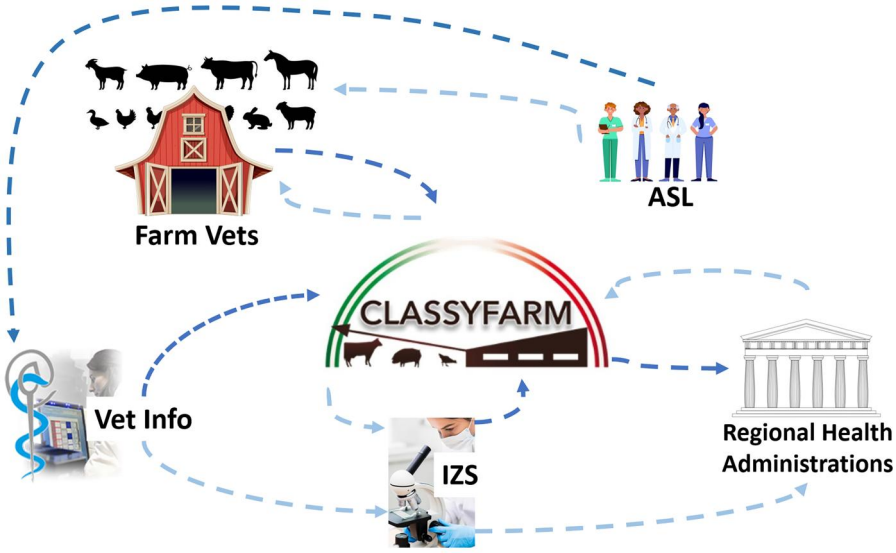

Figure 1. Visual representation of ClassyFarm within the system. The flow chart exemplifies the place and role of ClassyFarm in a system of relationships, which finally impacts public health. In this case, antimicrobial use (AMU) is observed in particular, and some simplification of the system is adopted. The inner frame focuses on the technical process allowing ClassyFarm to comply with its mission (to provide information to public and private actors). Raw information supplied by farmers (here considered as managers of animal production units), duly processed and elaborated, supply the system with the typical ClassyFarm output (information) to the benefit of several units of the system: mainly policy makers and research organisations but also providing feedback to farmers themselves to improve animal health and reduce AMU. At a wider level, reduced AMU can benefit the environment and animal food safety, thus reducing the burden of disease related to antimicrobial resistance (AMR) humans (with related public and private costs) ASL: Azienda Sanitaria Locale (Local Health Unit); Vet Info: National Veterinary Information system.

and welfare collected by the competent veterinary authorities during official controls and those resulting from self-control, recorded by the farm veterinarians. Such data are integrated with further information acquired by the databases of other systems in the National Veterinary Information system (VetInfo; https://www.vetinfo.it/), namely the National Animal Register (BDN), which provides information on farms and animal populations, and the database of the National Electronic Veterinary Prescription system (REV).

As for the internal organisation, ClassyFarm can be described as an information hub which processes information from both existing IT facilities and *ad hoc* information provided by private and public institutions (farm vets, public health vets, public institutions) (Figure 2). ClassyFarm allows livestock farmers to check how they perform compared to the average regarding biosecurity, animal welfare and AMU, to identify areas for improvement and verify the most effective measures to reduce the level of farm risk. The system allows competent authorities to plan targeted controls with savings for the public administration in terms of financial and human resources. Furthermore, such system will lead to a reduction of audits for operators compliant with current legislation.

Regarding AMU/AMR, ClassyFarm acquires raw data from other systems databases for further analysis and makes them available to users *via* its business intelligence dashboards. Currently, ClassyFarm estimates AMU in pig, poultry and ruminants (bovine, buffalo, goat and sheep) farms; other livestock species will be included in the future. The coverage is nationwide and the inclusion of a farm in the system is automatic. The AMU is calculated using a national indicator (DDDAit – defined daily dose animal for Italy), combining information from the REV and the BDN. Benchmarking of a farm is performed by comparing its AMU with the median and weighted (on herd size) mean of the farms of the same production type (e.g. fattening pig farms, dairy cow farms). Registered users can visualise farm data *via* dashboards created with Microsoft Power BI (Microsoft Corporation, Redmond, WA). Figures 3 and 4 show an example of a farm dashboard. Data on AMR are supplied by several public laboratories that provide diagnostic services to farmers. The dashboards are in an advanced testing phase. The surveillance of AMR on domestic animals has been implemented and will be integrated in ClassyFarm; surveillance on selected wildlife species (e.g. wild boars, wild birds, micro-mammals, etc.) has also started.

Surveillance system evaluation

We used three evaluation tools to evaluate ClassyFarm: the FAO Progressive Management Pathway for AMR

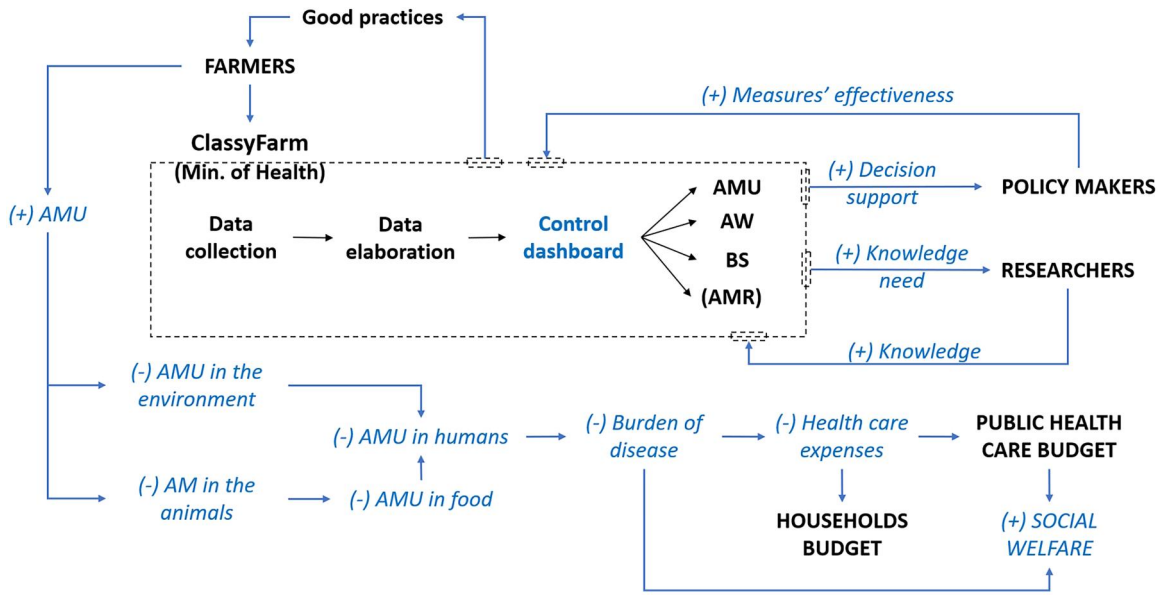

Figure 2. Visual representation of ClassyFarm as system hub. This figure is meant to complete Figure 1 focusing, in this case, the flux of information from and to the context where it operates. Besides the information from animal production, ClassyFarm is fed with data originating from Central and regional administrations and organisations of the public health system, namely VetInfo, IZS, ASL (local units of the National Health System). In turn, ClassyFarm's output is used by most of these organisations to optimise veterinary field controls and prospect general and targeted policy measures, with potential gains of effectiveness and efficiency. This reinforces the idea of ClassyFarm as an information hub placed within a complex health system, though making more complex the economic evaluation. AW: animal welfare; BS: biosecurity.

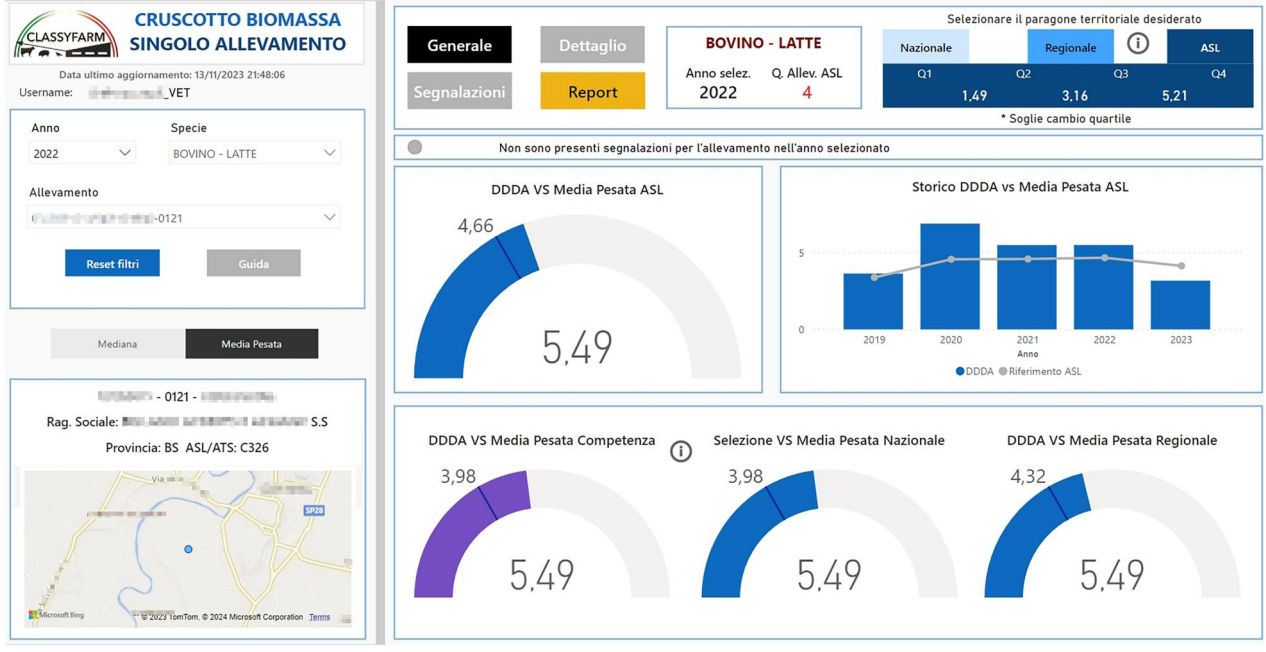

Figure 3. Example of a 'general' view of the antimicrobial use (AMU) dashboard of an individual farm in the ClassyFarm system, depicting a dairy cattle farm with AMU in 2022 above the weighted means. On the left side, it is possible to select the farm, the type of benchmarking (median or weighted mean) and to view the location of the selected farm on a map. At the top, it is possible to select the type of data to be displayed (general or detailed), to download a pdf report on the AMU over the past three years, to select the type of administrative area for benchmarking (national, regional, local) and to view the quartiles thresholds for the selected area. The larger gauge in the Middle shows the AMU of the farm compared to the benchmark of the selected administrative area, in this example the local area (ASL). The vertical bar graph displays the trend of the AMU over the years compared the benchmark (dots and grey line). The purple gauge depicts the AMU of the farm compared to the benchmarking of all the farms that a user is authorised to view. The other two adjacent gauges show the AMU of the farm compared to the benchmarking of the unselected administrative areas (national and regional in the example).

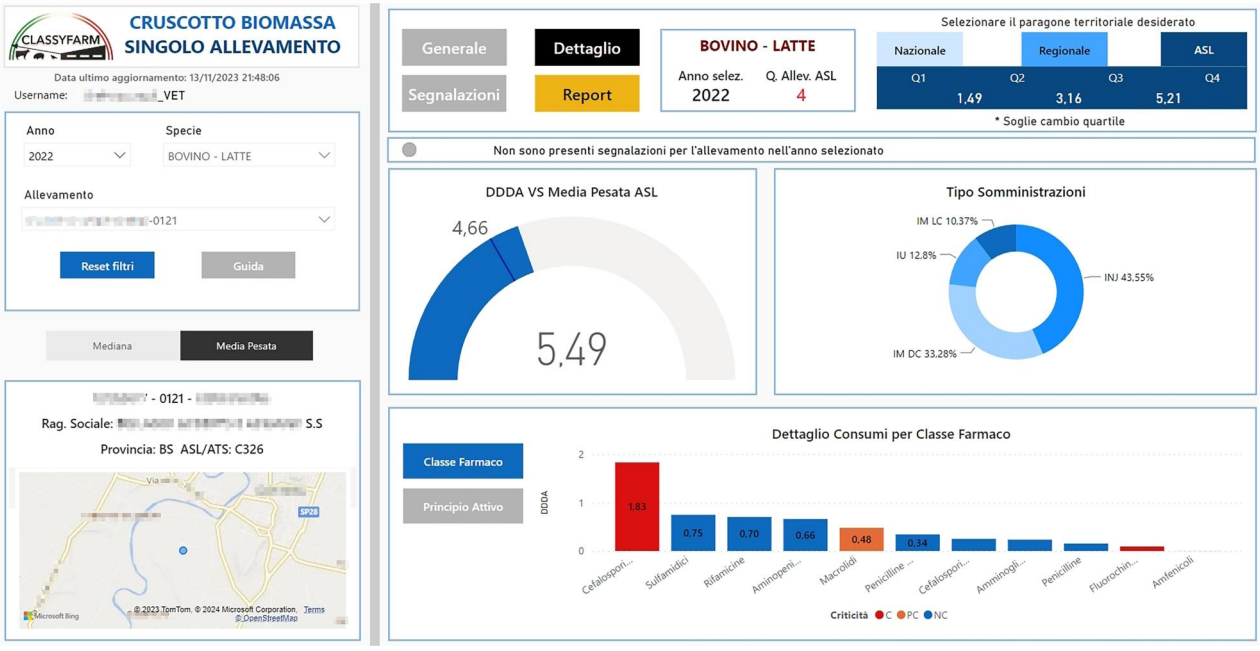

Figure 4. Example of a 'detailed' view of the antimicrobial use (AMU) dashboard of an individual farm in the ClassyFarm system, depicting the same dairy cattle farm detailed in Figure 3. The doughnut graph displays the AMU by route of administration (injectable, intrauterine, intramammary, etc.). the vertical bar graph shows the AMU by antimicrobial class (selected in this example) or active ingredient. Third and fourth generation cephalosporins, quinolones and polymyxins are highlighted in red; macrolides are highlighted in orange.

(FAO PMP-AMR), the Network for Evaluation of One Health (NEOH) tool, and OH-EpiCap.

The PMP-AMR was developed by FAO to provide guidance to countries for developing and operationalising their multi-sector OH National Action Plans (NAP) on AMR through a stepwise approach (FAO 2019). Since questions are aimed at analysing a OH NAP, they were not all relevant to evaluate specifically the ClassyFarm system, which mainly deals with the animal production sector. However, we used the tool for self-assessment, to measure progress in achieving an optimal and sustainable use of antimicrobials. The tool is based on four focus areas: awareness, evidence, governance, and practices; for each of them, specific activities, achievements, and key performance indicators (KPI) are listed. The evaluators score activities and indicators according to relevance in a spreadsheet, which, which automatically shows the output in a dashboard. We applied a beta version of the tool, which was provided by FAO upon request.

The NEOH tool was elaborated within the framework of the EU COST Action TD1404 "Network for the Evaluation of One Health" (NEOH) to provide science-based guidance for the evaluation of OH and other integrated approaches to health. It assesses the extent to which the six dimensions of knowledge integration (systems thinking, planning, transdisciplinary working, sharing, learning and systemic organisation) are implemented in a given OH initiative. Scores attributed to qualitative and semi-quantitative items are entered in a spreadsheet for the evaluation for the evaluation of the degree of OH implementation or "OH-ness"; a OH index and OH ratio are automatically calculated and illustrated in spider diagrams with the relevant distribution of scores. The tool is freely available (Rüegg et al. 2018).

OH-EpiCap was developed by the MATRIX consortium, funded by the One Health European Joint Program, to systematise the characterisation of epidemiological surveillance activities in national surveillance systems (Tegegne et al. 2023). It was created to characterise, assess and monitor the OH epidemiological surveillance capacities and capabilities, across three dimensions: organisation, operational activities, and impact of the surveillance system. A beta version of this tool was used for the evaluation. The tool is an interactive web application, in which the users can fill the questionnaire, giving scores from 1 (low degree of OH-ness) to 4 (high degree). Answers are automatically analysed and results are shown as radar charts and lollipop plots. The tool is freely available at: https://freddietafreeth.shinyapps.io/OH-EpiCap/

The evaluations with FAO-PMP and NEOH tools were performed through key informants' interviews. Evaluation was carried out twice, in autumn 2019 and summer 2022, in order to assess changes over time in

the functionality, implementation/progress (FAO-PMP) and in the OH-ness (NEOH) of ClassyFarm. Interviewees were selected using purposive sampling; we selected participants that had the potential to provide relevant, comprehensive and diverse information about the research questions (Tong, Sainsbury, & Crai, 2007). In total, 16 participants were selected, including representatives of the ClassyFarm management team ($n = 3$), farm veterinarians ($n = 2$), veterinarians from the National Health System ($n = 4$), farmers and livestock industry operators ($n = 4$), and academics/experts in AMR/AMU ($n = 3$). Two assessors (LT, DDM) organised in person meetings; each interview lasted around one and a half hour, and answers were recorded through written notes. The questions asked referred to the set of questions embedded in each evaluation tool. The assessors reached a consensus among the different answers provided by interviewees and entered the scores in the respective Excel spreadsheets.

OH-EpiCap evaluation was carried out in 2022; it was initially performed based on the two assessors' knowledge (LT, DDM), gained in the previous evaluations with NEOH and FAO-PMP. Afterwards, two subsequent virtual meetings lasting one hour with three members of the ClassyFarm management team were carried out and a consensus on the shared answers options was reached for each question; notes were taken to justify the answers provided. The aim of this evaluation was to assess again the OH-ness of the system using a quicker and more user-friendly tool, which includes an 'impact' dimension useful to discuss the outcomes of the evaluation and possible adaptations.

Results and discussion

Evaluation with PMP-AMR

The dashboard illustrating the scores attributed to overall activities and key performance indicators in the four focus areas of the tool are shown in Table 1.

The 'awareness' focus area refers to progress made in raising awareness and understanding of AMR through communication, education and training. Stage 1 (assessing awareness) did not vary between 2019 and 2022, since the first activity (identification of stakeholders) had already been completed in 2019, while the other activities (awareness assessment, inventory of existing training opportunities, etc.) were not foreseen by the surveillance system. Stage 2 (limited or small-scale AMR awareness) improved, since the design of campaigns targeting the key stakeholders and veterinary related professionals had started in 2019, and it was concluded by 2022. Already in 2019, core curricula had been reviewed to ensure coverage of AMR/AMU topics in dedicated courses for undergraduate and graduating vets. All activities foreseen under Stage 3 (nationwide awareness of AMR in some sectors) were performed and completed in the animal science sector as at 2022. As regards Stage 4 (nationwide awareness of AMR in all sectors), slight improvements were achieved by 2022, though not shown on the dashboard percentage and KPI. Training courses promoting successful alternatives for AMU were indeed implemented for food professionals but not for agriculture students; annual reports on the evolution AMU and AMR incidence based on surveillance/monitoring data is available only for animals and humans, not yet for the environmental sector; as for Stage 1, awareness campaigns were not foreseen by the surveillance system.

Table 1. Percentage of achievement considering the overall activities and key performance indicators in the four focus areas of the FAO PMP-AMR evaluation tool, applied to ClassyFarm system in 2019 and 2022.

		First evaluation – 2019		Second evaluation – 2022	
Focus area	Stage	Overall %	KPI %	Overall %	KPI %
Awareness	1	25	50	25	50
	2	25	0	100	100
	3	60	60	100	100
	4	0	0	0	0
Evidence	1	83	80	100	100
	2	40	40	100	100
	3	63	60	100	100
	4	60	60	80	80
Governance	1	63	0	100	100
	2	71	67	71	67
	3	100	100	100	100
	4	100	100	100	100
Practice	1	50	67	100	100
	2	50	67	83	100
	3	71	67	86	83
	4	17	0	17	0

KPI: Key performance indicators.

The 'evidence' focus area refers to the surveillance and monitoring of AMR and AMU, as a basis for driving action. As regards Stage 1 (system development), the implementation of surveillance plans and the laboratory capacity was completed already in 2019, and – as at 2022 – also the routes and flows of antimicrobial use and sales were mapped thanks to the adoption of the REV by the Veterinary Public Health Sector. Accordingly, the Stage 2 (focus AMU and AMR surveillance) activities referring to the implementation of surveillance for antimicrobial residues in animal products for food consumption and laboratory capacity for surveillance on AMR and residues, had been completed already as at 2019. In 2022, data collection/reporting on AMU and AMs sold and AMR surveillance

(at small scale) in animal products were also completed. All Stage 3 (Nationwide AMU and AMR surveillance in some sectors) activities/achievements were considered completed in 2022; in 2019, some activities were still in progress, i.e. end-users benchmarking, reporting on AMs sold by antimicrobial class, and AMR surveillance (at national scale) in animal products. Stage 4 (Nationwide AMU and AMR surveillance in all sectors) actions were completed in 2022, except for the plant production sector.

The 'governance' focus area refers to the political commitment, policy improvement, regulatory frameworks that provide the capacity and resources to contrast AMR. It reached already good scores in 2019. Stage 1 (establish a governance mechanism) further improved with the new PNCAR 2022–2025, in which representatives of Ministry of Agriculture and Ministry of Ecological Transition were involved. We did not observe substantial progresses in Stage 2 (situational analysis and assessment), since data on AMR burden in the plant and environmental sectors are still not delivered and reviewed by the key stakeholders, and the assessment of stakeholders' behaviour as to AMR drivers is yet partial. Stage 3 (strategic and operational planning) and 4 (National 'One Health' action plan implementation and review) activities were considered already completed as at 2019.

The 'practice' focus area refers to the development of good practices in food and agriculture systems to minimise the use of drugs and the spread of AMR. According to our evaluation, it progressed over time as regards the first three stages. Foreseen Stage 1 (Regional promotion of Good Practices) activities regarding national aspects (regulation of AMU and overall AMs good practices) were all implemented in 2019, while small-scale initiatives supporting prudent AMU were completed in 2022. Stage 2 (National promotion of Good Practices) activities were considered completed in 2022, except for legislation and guidelines to regulate prudent use of animal wastes as fertilisers to plant-based food. Activities such as the development of national best practices for prudent AMU in priority animal production sectors and initiatives that support prudent AMU on livestock farms were completed in 2022. Stage 3 (National implementation of Good Practices) activities were considered completed in 2022, except for benchmarking of veterinary professionals, which is not foreseen by the system. Stage 4 (National implementation of 'One Health' Good Practices) activities are implemented in the animal production sector, but not in the other agriculture sectors; coaching of livestock production professionals to change behaviour regarding AMR and AMU has started as at 2022.

In conclusion, FAO PMP-AMR highlighted progresses in raising AMR awareness, in particular through campaigns targeting some key stakeholders and veterinarians, and the promotion of good practices in food and agriculture systems. It indicated that significant progress has been made in the surveillance of AMU/AMR and in the establishment of governance mechanisms. However, the evaluation highlighted that some important gaps remain, especially regarding the environmental sector.

Evaluation with NEOH

Mean scores of OH aspects (Table 2) suggest uneven balance between operations and infrastructures of the surveillance system in place, as it can be observed in the spider diagram in both 2019 and 2022 evaluations (Figure 5). The components 'thinking' and 'systemic organisation' slightly improved over time.

Regarding OH thinking, different dimensions and scales were identified as being relevant elements within the initiative. The surveillance system is strictly linked to the national and EU regulations on AMU/AMR and ClassyFarm is instrumental to the PNCAR. Time scale is relevant since the system has evolved, from its inception, from a system monitoring welfare and biosecurity on farms, towards a more integrated approach; also, the variety of livestock species considered, and the number of farms adhering, has been growing. The economic dimension is also fundamental, at different scales, both in terms of investments and cost-benefits for farmers. Socio-ecological systems related to animal health and production are considered, with impacts on human and environmental health. At the second evaluation, we obtained a higher score for OH thinking since the system has started to consider also the environmental pillar.

As regards OH planning, although the initiative is mainly animal-health oriented, the general principle beyond the initiative is OH-oriented: fighting AMR in

Table 2. Scores attributed to operational and infrastructural dimensions of ClassyFarm with NEOH tool in two evaluations (2019 and 2022).

	Thinking	Planning	Working	Learning	Sharing	Systemic Organisation
1st evaluation (2019)	0.60	0.60	0.55	0.58	0.90	0.70
2nd evaluation (2022)	0.70	0.60	0.55	0.59	0.90	0.80

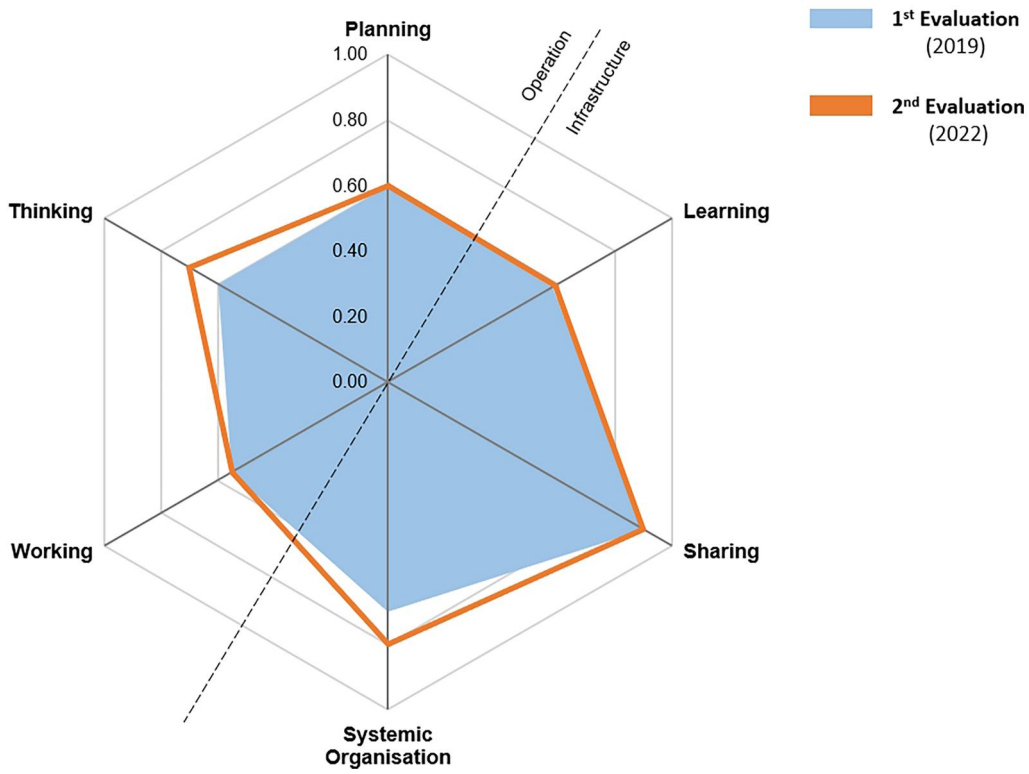

Figure 5. Spider diagrams illustrating the degree of One Health implementation and the balance between the operational and the supporting mean values of ClassyFarm surveillance on AMU/AMR in 2019 (light blue shade) and in 2022 (orange line). The diagrams are generated by the NEOH the NEOH spreadsheet (Rüegg et al. 2018).

animals with the aim of protecting also human and environmental health. However, a dominant role is played by veterinarians and the other actors in the animal/food production chain. Especially at the start of the initiative, a limited number of stakeholders from some geographic areas (characterized by intensive livestock production system) was involved; stakeholders participated in planning and adjustments of ClassyFarm throughout the different phases of the initiative. Time and budget allocated for self-assessment of the initiative and for its objectives are somewhat adequate, but human resources are considered not sufficient.

Regarding OH working, an intermediate diversity of disciplines (animal/biological/computer science, public health), methods (epidemiological data collection, diagnostics, computational models) and actors (including non-scientific community) is involved in the initiative, but the level of integration and collaboration is still limited.

As regards OH sharing, optimal scores are related to data/information quality and storage. Internal mechanisms for sharing information and awareness are better than external mechanisms; indeed, more resources are needed, especially in terms of personnel, for sharing. Results are shared between groups, though privilege of access to data is restricted to certain categories. Institutional memory and resilience to change obtained the highest score.

The OH learning reflects a fair cooperation among the stakeholders involved at different levels in the initiative. Stakeholders' involvement and awareness has supported the adaptive learning of the health system. At organisational level, generative learning rarely occurs, as collected information rarely leads to change in fundamentals and objectives.

As regards systemic organisation, teamwork is good, with effective cooperation within and amongst working groups, and between regional groups and the national ClassyFarm coordinating team; the coordinating team has a strong leadership. Being the initiative focused on animal health and production, the OH challenge is not adequately tackled; scientific and developmental questions and innovations provided by the initiative mainly concern the animal sector. Over the time, the team interrelations and working cooperation got up to speed, and we obtained a higher score for systemic organisation in the second evaluation.

The evaluation with NEOH tool enabled us to go in depth into the system in which ClassyFarm is

embedded. It revealed an imbalance between surveillance system operations and infrastructures, and showed that the integration and collaboration among disciplines is still limited, since the system remains focused on the livestock sector. Internal data sharing exists but more external sharing is needed; moreover, although stakeholder involvement and collaboration have improved, generative learning is rather scarce. On the other hand, NEOH highlighted some progresses in the system, in terms of compliance, timelines, completeness (e.g. with the inclusion of new animal categories/species).

Evaluation with OH-EpiCap

ClassyFarm system scored sub-optimally in the three dimensions identified by the OH-EpiCap tool, with a 50% EpiCap Index and no targets showing good adherence to One Health principles. The average evaluation score of ClassyFarm among all questions that compose each of the target areas covered by the OH-EpiCap tool are shown in Figure 6, while radar charts specific for the three tool dimensions can be found in Supplementary Figure 1.

Dimension 1 (Organisation) deals with different aspects related to the organisation of the OH surveillance system, including formalisation, coverage, resources, evaluation and resilience. The organisation dimension reached a 54% score, with ten indicators out of 16 scoring '3' and the remaining scoring '2' (Supplementary Figure 1). The aim of ClassyFarm system was defined from the expectations of both private and public stakeholders from the animal health and livestock production sectors. However, as veterinary public health in Italy falls under the Ministry of Health, ClassyFarm is mainly the responsibility of this Ministry. Recently, the Ministry of Agriculture has also become involved in the governance due to the role of ClassyFarm in the allocation of part of the CAP funds. The coordination activities are well defined, even though they are not shared between sectors yet; a progression towards a shared coordination at most levels of surveillance is foreseen. As regards the transdisciplinarity of the AMR surveillance system, as

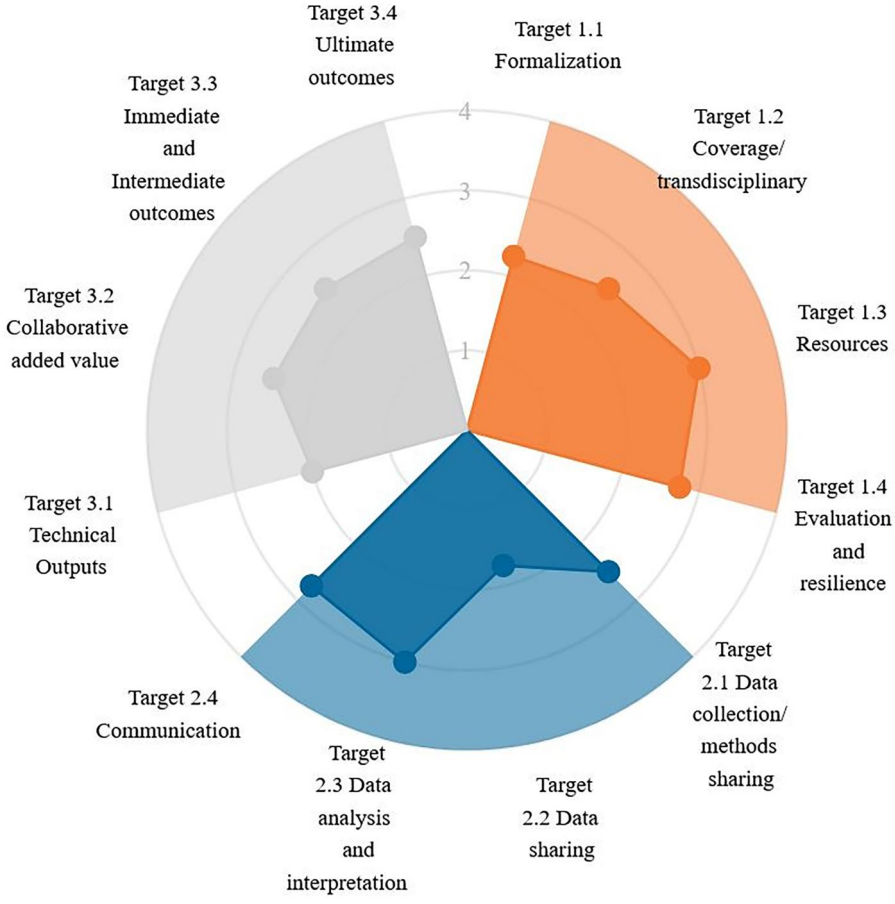

Figure 6. Average scores of ClassyFarm in the target areas covered by the OH-EpiCap tool, segmented into three dimensions (1 = organisation, 2 = operational activities, 3 = impact). The radar chart was generated in the EpiCap web application (https://freddietafreeth.shinyapps.io/OH-EpiCap/).

anticipated, the animal health and production components are the most represented sectors in ClassyFarm, although the environmental sector has started to play a more active role (e.g. study of AMR genes in the farming/agriculture environment, wastewater, freshwater, etc.). The human health sector has an indirect linkage as regards public health implications of the agriculture and livestock production system. Several disciplines relevant to AMR surveillance, besides the 'traditional' life science, are being included, such as economics and social sciences. Most categories of relevant actors are included, although the general public is still poorly involved in the surveillance system. Poor citizen participation in OH initiatives is also reported by Hitziger et al. (2021), and efforts should be done to fill this gap. Regarding resources, EpiCap considers budget, human resources, shared materials and equipment, and training; the budget component allocated was considered sustainable, but not sufficient, as well as the human resources. Raw data are shared on demand within the Ministry of Health at national and regional level. ClassyFarm experts contribute to *ad hoc* meetings at the Ministries of Health and of Agriculture. Training related to ClassyFarm is appropriate, but not sufficient, and it does not specifically address the OH approach. As regards the evaluation and resilience of the surveillance system, internal evaluations (e.g. data checks and validations, software testing, stress tests) are carried out, but they are neither regular nor systematic and do not allow for a complete monitoring of the system. External evaluation was conducted within the CoEvalAMR project, using different evaluation tools (NEOH, FAO-PMP, OH-EpiCap), as illustrated in this paper. Corrective measures recommended by some of the stakeholders have been already implemented; however, the feedback from stakeholders is not systematic and needs improvements. Other corrective measures (e.g. revision and introduction of new interactive dashboards), suggested by the evaluators themselves, have been implemented. The system has the ability to adjust itself to improve its functioning and to adapt to changes in the coverage or organisation; even, it has the ability to adapt to innovation and new activities. Nevertheless, changes are slowed-down due to bureaucracy and the fragmentation of the Italian health system, which is centralised in its policies but managed at local/regional level (Italy is divided in 20 administrative 'Regions').

Dimension 2 (Operational activities) deals with different aspects related to OH-ness in operational activities, namely data collection and methods and data sharing, data analysis and interpretation, communication. Overall, this dimension reached a 50% score. One indicator ('sharing expertise') showed good adherence to OH principles; 'FAIR data' (under Findability, Accessibility, Interoperability and Reusability principles) was the indicator that would most benefit from improvement (Supplementary Figure 1). Surveillance protocols are designed through the collaboration among actors from various sectors; more recently, the environmental sector has been included for the control of residues in wastewaters (from urban environments, animal husbandry and agro-industry). Most of the laboratory techniques for AMR detection and procedures are harmonised within the national veterinary laboratory network; ClassyFarm triggered such harmonisation process. Data collection for surveillance is mainly intra-sectoral (animal health/production sectors); however, data are going to be collected also for the environmental sector. Data collected are stored in a central repository accessible through the ClassyFarm dashboard. Data sharing agreements are implemented between actors within sectors. Data quality is evaluated but not yet systematic. Data sharing is limited between actors within the animal health/production sectors, but the system is moving towards data sharing with the environmental and human components. So far, data meet only partially the FAIR principles, so improvements are needed. Joint data analyses and sharing of techniques (statistical analyses, visualisation procedures) are foreseen across the animal and human sectors. Scientific expertise is shared across all sectors; this indicator showed good adherence to OH principles according to OH-EpiCap. Internal and external communication is fairly established, involving actors across different sectors, which in some occasions jointly disseminate information to decision-makers. Nevertheless, communication should be further improved, for example by publishing annual reports on the aggregated results and documents aimed at a more general audience (e.g. infographics and dissemination videos). Information related to suspicion or detection of emerging AMR agents is shared mostly between actors within the animal sector.

Dimension 3 (Impact) deals with the impact of the OH surveillance system, including the following targets: technical outputs, collaborative added value, and immediate, intermediate and ultimate outcomes. The dimension reached a 46% score. One indicator ('strategy') demonstrated good adherence to OH principles. The indicators that would most benefit from improvement are 'operational cost', 'OH team', 'health outcome'. Questions on emergence detection,

interventions, and preparedness were considered not applicable in our AMR surveillance context (Supplementary Figure 1). ClassyFarm made it possible a knowledge improvement on the epidemiological situation of AMR in livestock, but outreach activities to the general public are still limited. The overall effectiveness of the surveillance is evaluated, but improvements will likely need more time to be demonstrated, being AMR a complex issue. An evaluation of the operational costs of surveillance activities in the animal health sector is being implemented. A multidisciplinary team is present, although its composition is not OH-oriented; indeed, a OH team was not a primary objective of ClassyFarm. The network of stakeholders has been strengthened by the surveillance system. Stakeholders mainly belong to the animal health/production sectors (public health officers, veterinarians, producers, farmers, etc.). ClassyFarm has an effective international collaboration with animal health/production experts involved in biosecurity (e.g. Biocheck.UGent; https://biocheckgent.com). Regarding AMR surveillance, international collaboration is for now limited to research projects. Extensive advocacy activities are conducted within the surveillance system and several stakeholders are involved, but their effectiveness should be evaluated. Thanks to the surveillance system, awareness has improved among stakeholders within the animal health and production sectors; however, better communication is needed to reach all relevant stakeholders. Multi-sectoral research collaborations have been initiated between actors across various sectors, especially with the human health sector. Some changes in national AMR surveillance policy have been made thanks to outputs of the animal sector surveillance; for example, the new PNCAR now includes the agriculture and environmental sectors besides human and animal health. Thinking about behavioural changes, new attitudes and habits, aimed at reducing risks related to AMR, have been observed among animal breeders, vets and other professionals in the animal production system. Further interventions or activities are needed to reinforce behavioural changes and to impact on the general public. The outcomes of surveillance on population health have not been evaluated and time is needed to implement such step forward; however, it will be difficult to evaluate, due to the lack of a benchmark.

OH-EpiCap enabled to evaluate the degree of OH in the surveillance systems; even though the evaluation was not so in-depth, the assessment was quick and allowed to identify gaps and discuss the possibility of implementing measures for improving the system (Moura et al. 2023a). The assessment resulted in suboptimal OH scores and no clear adherence to OH principles, being ClassyFarm primarily focused on livestock. However, it detected progresses in terms of organisation and operational activities, and towards a higher transdisciplinarity, with the involvement from the environmental sector. The evaluation indicated that the system is evolving, with room for improvement in resource allocation, data sharing and communication.

Overall evaluation

ClassyFarm has been developed mainly for the surveillance of livestock farms, so it focuses on animal health and production. Thus, it will not be possible to achieve a full integration of animal-human-environment surveillance on AMU/AMR directly within ClassyFarm. However, ClassyFarm 'OH-ness' could certainly be improved. For example, the system has a database on AMU/AMR that could be exploited within a broader framework including also the human sector, and surveillance on the environmental component could be better integrated in the system.

As regards the environmental pillar, this was also considered as the weakest in the integrated AMR surveillance programs carried out in Denmark and in Norway (Moura et al. 2023b; Norström et al. 2023). However, both programs showed good adherence to OH principles when evaluated with the OH-EpiCap tool. In fact, they have been created to monitor AMR in both the veterinary and the human sector, and they have now been implemented for over 20 years.

In Italy, policies to tackle AMR with an integrated approach are more recent. ClassyFarm has so far promoted the integration between AMU and AMR data in the animal sector. This is demonstrated by the development of new methods, tools and standardised SOP, as well as joint projects, across the surveillance components. Moreover, awareness among professionals on the global significance of AMR and AMU has increased, with changes in stakeholders' behaviours and practices aimed at preventing and reducing the use of antimicrobials. Finally, there is an encouraging reduction in the use of some highest priority critically important antimicrobials (HPCIAs) in Italian livestock, e.g. colistin and 3^{rd}–4^{th} generation cephalosporins (European Medicines Agency, 2022). However, it is difficult to say whether all these progresses have been triggered by the integrated surveillance in itself, since they could be linked to the official controls carried out

within ClassyFarm, and to the economic advantages for farms that decrease AMU.

The evaluation of surveillance impacts is still a challenge (Aenishaenslin et al. 2021). Some Authors identified possible indicators of the performance of integrated surveillance systems for AMU/AMR: Bennani et al. (2021) cite the capacity of the system to produce information and use it, and to provide a OH response to AMR threats. However, it is still unclear how to measure these indicators, also due to the lack of benchmarks. Some studies have evaluated the economic impact of OH surveillance (Queenan et al. 2016). Regarding costs, the ClassyFarm case study features a specific complexity: if the cost of the system itself can be easily evaluated, the value of the information that ClassyFarm retrieves from the other databases of the public health system is difficult to assess, since this information serves multiple purposes in the health system. Therefore, the conceptual framework of costs will require further evaluation.

Conclusions

The evaluation tools adopted in our study have different characteristics as regards the evaluation objectives, depth of analysis, and time/training resources to perform the evaluation (Sandberg et al. 2021). No tool can cover all evaluation aspects comprehensively, and in a user-friendly manner (Alban et al. 2023). All three methods were useful to analyse the operationalisation of surveillance, with a focus on OH implementation. NEOH was more focused on the systemic understanding of OH activity and theory of change; OH-EpiCap addressed operational aspects and outcomes of surveillance; PMP-AMR evaluated the surveillance path focusing specifically on AMR. Each of the tools enabled to gather different information, highlighted strengths and weaknesses of ClassyFarm and served as a basis for the discussion of possible adaptations and improvements to ensure the system efficacy and effectiveness.

Our evaluation highlighted ClassyFarm evolution from a barely biosecurity and welfare surveillance system towards an integrated approach. Considering this progression, we expect evaluation scores to improve in the future. Future reassessments at regular intervals, at least using OH-EpiCap, will enable to detect such improvements.

Finally, future evaluations covering the entire NAP and bringing together stakeholders of different health sectors could be particularly useful to encourage collaboration discipline and enhance the OH-ness of AMR/AMU surveillance.

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Ethics statement

An informed consent was obtained at the beginning of the interviews, where the participants were informed that data collected were anonymous. This study follows the principles of the Declaration of Helsinki.

Author contributions

Conceptualisation: LT, DDM, MA, CR, FS, GLA. Investigation: LT, DDM, FS, NF, GLA. Writing – original draft: LT, DDM. Writing – review & editing: all authors.

Disclosure statement

No potential conflict of interest was reported by the author(s).

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Data availability statement

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author.

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