A scoping review of feed interventions and livelihoods of small-scale livestock keepers

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Livestock support the livelihoods of one billion people in Africa, Asia and Latin America, but the productivity of animals remains low, reducing the potential of the sector to support higher incomes and better nutrition. Improved livestock feeding has been identified as the most important step towards higher productivity. This scoping review assessed the evidence for the uptake of improved ruminant livestock feed options, the effect of this uptake on livestock productivity and the degree to which this improves smallholder farmer livelihoods. In total, 22,981 papers were identified, of which 73 papers were included in the final analysis after a rigorous double-blind screening review. Only papers that reported farmers’ decision to use a new feed intervention were selected, thereby excluding feeding trials and participatory feed assessments. Of the 73 papers, only 6 reported combined evidence of adoption, effect on productivity and livelihood changes. A total of 58 papers looked at adoption, 19 at productivity change and 22 at livelihood change. This scoping review highlights the gap in evidence for the adoption of new livestock feeding practices and provides recommendations to support farmers’ uptake of feed interventions.
A livestock feed intervention aims at changing practices to provide more or better feed, increasing livestock productivity. The feed interventions considered in this scoping review are of three types:

1. Improved grasses and legumes—ruminant animals naturally consume grass, forbs or shrubby vegetation. Natural pastures, while of moderate quality, are an important feed source in low-income countries. ‘Improved’ species include naturally high-yielding tropical grasses such as *Brachiaria* or *Pennisetum* species as well as high-quality legume species such as vetches or *Desmodium*. If well managed, introduced grasses can greatly increase feed yields, while introduced high-protein legumes can complement basal feeds such as straws and natural pasture.

2. Multipurpose trees—trees are important in mixed crop–livestock systems, providing multiple benefits to small-scale farmers, including livestock feed. Various (mainly leguminous) trees have been popularized in tropical regions over recent decades. If well managed, these can provide a highly digestible and high-protein livestock feed and are reasonably resilient to dry spells.

3. Increasing the intake and nutritive value of crop residues—crop residues make up a large part of ruminant livestock feed across the tropics, particularly in semi-intensive crop–livestock systems. Residues include straws of cereals such as wheat, barley and rice; stems or leaves of cereals such as maize and sorghum; and legume straws or haulms. Crop residues are generally characterized by low nutrient density, especially cereal straws. Methods such as physical and chemical treatments as well as the selection of superior varieties have been developed to improve nutrient availability.

Other feed interventions include preserving fresh feed, filling seasonal gaps and feeding with high-quality supplements.

To describe global livestock production, various categorization approaches have been suggested. The most widely known was developed by Seré and Steinfeld and further operationalized by Thornton et al. It is based on major climate and land-use categories for which data are available globally and that determine the livestock feed base: permanent grasslands support pastoral systems, which often involve seasonal movement of livestock and are focused on ruminants; land areas that are used for both cropping and grazing are home to agro-pastoral and smallholder mixed crop–livestock systems, with or without irrigation; and landless systems rely solely on purchased feeds and are typically dominated by monogastric species, such as chickens and pigs, although landless urban dairy systems and feedlot beef systems also exist. More recently, researchers have suggested expanding this categorization to also consider the potential for the intensification of production, because of its considerable implications for development, using the evolution from subsistence to market orientation as a proxy.

### Types of feed interventions and impact pathway

The majority of papers (53) dealt with planted fodder, while agroforestry was the topic of 26 papers and crop residues 7 papers (Table 1). Most papers assessed one type of feed intervention (30 papers on planted fodder only, and 13 and 4 for agroforestry and crop residues, respectively). There seemed to be a mismatch between the research effort on feed intervention types and the importance of the technologies in overall livestock feeding. Crop residues constitute a large part of feed resources in small-scale ruminant systems, and they have great potential to be even more productive. Yet less than one in ten articles dealt with crop residues. Crop residues have no dedicated discipline and low visibility in terms of impacts despite their ubiquity across tropical livestock systems. After harvest, crop residues are bulky and may be complex to manage, in terms of storage, labour demand and seasonal availability. In contrast, about a third of the papers covered agroforestry interventions, a relatively less prominent feed option in these systems. This may be explained by the fact that agroforestry is used for feed as well as soil fertility, among other purposes. There could also be greater charisma associated with trees than with straw.

This scoping review analysed the impact pathway between adoption, livestock productivity and household livelihoods (Table 2), considering three main outcomes. The first was about the uptake, or adoption, of feed technologies (58 papers). We considered studies of livestock keepers using new feed interventions as part of their usual management practices independent of incentives-based research or development projects. Second, we were interested in studies on livestock productivity increases including milk production, weight gain, better body condition or herd growth that resulted from a feed intervention (19 papers). The final outcome of interest was household livelihood indicators associated with the uptake of a new feed option and consequently improvements in livestock productivity (22 papers). Such livelihood changes included increased income from livestock and reduced workload. Of the 73 papers, only 6 analysed the entire pathway, reporting evidence of adoption, the effect on productivity and consequent livelihood changes.

Adoption is the first step along the livelihood pathway, and it was anticipated to feature in most papers, given that it is relatively easy to measure either as a yes/no decision or as the extent of...
adoption. We found 15 papers that did not explicitly report or analyse that first step but only reported a change in productivity and/or livelihood indicators among adopters. More frequently, papers reported livelihood changes compared to productivity changes. This may be explained by a focus on development goals, such as producers’ livelihoods, and by the technical challenges of measuring livestock productivity. Livelihood indicators such as income and diet are relatively well established, and tools are available to systematically report them. In contrast, livestock productivity indicators vary across species (such as milk yield, weight gain, herd size and fertility indicators), require demanding measurement protocols and are calculated using different periods (such as lactation, reproductive cycle, season and year), making comparisons difficult.

Across the three outcome sets, there were no specific differences in types of publication or years of publication. Studies in mixed systems dominated across all outcomes, with few papers covering agro-pastoral or pastoral systems. For regions, papers from East Africa were most common for adoption studies, while for livelihood outcomes, there was a relatively large number of papers from Southeast Asia (8 out of 22 papers), possibly driven by research in development projects implemented in that region. In terms of research methods, the general observation that studies were mixed-methods approaches for adoption studies, possibly reflecting the importance of not only analysing the decision-making processes quantitatively but also assessing the ‘why’ and the ‘how’ that are better captured using qualitative approaches. There was no qualitative study measuring productivity indicators.

Analysis of the results reported by the studies. The outcome indicator results reported in the studies are shown in Table 3. Although 43 studies reported the adoption of forages, only 32 included data that could be used to estimate adoption. The same pattern applied to the adoption of agroforestry practices and crop residues. Analysing the results as reported in these studies, we found that the ranges of livestock keepers adopting the technology varied widely, from 0 to 90% for forages, 8 to 87% for agroforestry and 20 to 86% for crop residues.

Productivity indicators included increase in milk yields, animal weight gain, improved body condition and growth in flock/herd size. The number of papers with sufficient data was very low, with only nine papers across the three feed interventions. Changes in productivity ranged from 7 to 61%, with only one paper reporting productivity change related to crop residues.

Finally, for livelihood indicators, the scoping review identified 22 papers with sufficient data across the three feed types, with 14 papers quantifying the impact. Household income change (8 papers) ranged from 6 to 285%, gross margins (3 papers) increased by 58 to 519% and labour or workload change (5 papers) from −24 to −70%.

Drivers of adoption. To better understand the reported changes, 25 papers were identified that explicitly examined the reasons for adoption. These were further examined for underlying drivers or constraints to adoption. Of the adoption drivers, the following were mentioned most often. Farmer experience or level of education was mentioned in ten papers; these variables are commonly collected as part of the household characterization in adoption studies and tend to.
to be associated with higher rates of adoption. Expected increased productivity or income from the livestock enterprise was mentioned in eight papers. This is of course among the primary reasons to promote improved feed technologies, so this factor is expected to be prominent. However, most of the papers did not indicate it. Eight papers mentioned access to extension or training. Many feed technologies require considerable technical skill to be successful or effective. These are often described as ‘knowledge-intensive’ technologies, such as forage seeds that require treatment or scoring to germinate and then need to be grown from seedlings. Extension and training may therefore be important to facilitate their successful implementation. Seven papers mentioned labour availability. Most improved feed technologies require the use of additional and regular labour, such as cutting and carrying planted forages to confined ruminants. Family labour may be supplemented in some seasons by casual wage labour or even full-time labour in more market-oriented enterprises. Six papers mentioned good market access; again, this factor is generally associated with higher rates of adoption and may be associated with higher livestock product prices or easier access to feed technologies such as germplasm. Other contributing factors, in descending order, were access to credit or off-farm income, market orientation of the enterprise, group membership or social pressure, and land scarcity. Only two studies indicated soil improvement as an adoption objective, although this is one of the main reasons that nitrogen-fixing leguminous forages are promoted.

Of the factors that were indicated as constraining the adoption of improved feed technologies, the following were mentioned most frequently. Increased labour requirement was mentioned in six papers; just as labour availability was indicated as an important driver of adoption, the labour requirement can be a constraining factor when that labour is not easily available. Little perception of net benefit was mentioned in four papers. Feeds are an intermediate output towards livestock production, and the final benefit may not be easily perceived immediately, particularly for fattening

| Categories           | Items in category | Total | Planted forages | Agroforestry | Crop residues |
|----------------------|-------------------|-------|----------------|--------------|--------------|
| Publication type     | Peer-reviewed journal article | 51 | 35 | 17 | 4 |
|                      | Book chapter      | 1 | 1 | 1 | |
|                      | Conference proceeding | 8 | 6 | 3 | 1 |
|                      | Report             | 6 | 6 | 2 | 1 |
|                      | Working paper      | 7 | 5 | 3 | 1 |
| Year of publication  | 2016–2019         | 15 | 13 | 3 | |
|                      | 2011–2015         | 21 | 15 | 3 | 4 |
|                      | 2001–2010         | 28 | 18 | 14 | 3 |
|                      | Before 2001       | 9 | 7 | 6 | |
| Agro-ecological zone | Mixed systems     | 53 | 35 | 21 | 6 |
|                      | Agro-pastoral systems | 10 | 8 | 3 | |
|                      | Pastoral systems  | 3 | 3 | 3 | |
|                      | Multiple systems  | 1 | 1 | 1 | 1 |
|                      | Other             | 2 | 2 | 2 | 1 |
|                      | (Blank)           | 4 | 4 | 1 | 1 |
| Region               | Horn of Africa    | 12 | 11 | 3 | |
|                      | East Africa       | 23 | 16 | 9 | 3 |
|                      | Central Africa    | 1 | 1 | 1 | |
|                      | West Africa       | 7 | 4 | 2 | 1 |
|                      | Southern Africa   | 5 | 1 | 3 | 1 |
|                      | South Asia        | 6 | 4 | 2 | 2 |
|                      | Southeast Asia    | 12 | 11 | 3 | |
|                      | East Asia         | 2 | 2 | 1 | 1 |
|                      | Latin America     | 5 | 3 | 3 | |
| Type of methods      | Quantitative      | 45 | 31 | 18 | 5 |
|                      | Qualitative       | 9 | 6 | 4 | |
|                      | Quantitative/qualitative | 19 | 15 | 4 | 2 |
| Duration of the experiment | >20 years      | 3 | 1 | 2 | |
|                      | 11–20 years       | 4 | 2 | 2 | 1 |
|                      | 1–5 years         | 22 | 17 | 8 | 1 |
|                      | 6–10 years        | 8 | 7 | 3 | |
|                      | NA                | 36 | 26 | 11 | 5 |
| Total                |                    | 73 | 53 | 26 | 7 |

NA, not applicable.
enterprises where nutritional benefits accrue over longer periods. Four papers mentioned difficult access to the technology or inputs. For some forage species, there may be limited systematic supply of seeds or planting material, and this is often a limit to sustained use after the withdrawal of project support. Many LMICs lack functioning forage seed systems. Four papers mentioned the complexity of the technology; as indicated, some feed technologies may require specific techniques, the training in which may not be available. Finally, competition with other land uses was mentioned in four papers. In land-scarce settings, priority may be given to food crops or to short-term cash crops such as seasonal vegetables, since these may represent a more profitable use of land. Likewise, some alternative land uses may be affected by subsidies and price control and may influence the relative returns from some feeding options.

Quality assessment. The research quality assessment was conducted using three indicators for all 73 papers (Table 4). In terms of study methodology, 17 papers scored high, and almost half of the papers (32) scored low. The quality assessment on the justification of the study methodology was slightly better, with 31 papers being scored high. The scores for the overall quality were relatively evenly distributed, with 17 papers having the highest scores and 15 the lowest ones. Overall, the quality of the papers was judged to be average to low. Both the number and quality of studies that were included in this analysis are rather disappointing, given the role that improved feed options can and should play in enhancing livestock productivity and household livelihoods.

Discussion

First, it is worth noting that the scoping review identified very few studies that answer our research question on the comparative impacts of various ruminant feed interventions on the livelihoods of livestock keepers. Indeed, the exercise yielded only 73 papers from a starting population of 22,981. We found many papers that studied the technical aspects of feed supply for ruminant livestock but were excluded because they did not assess the interventions’ uptake by or usefulness to farmers. This points to a strong bias among the scientific community towards understanding the technical

| Categories                      | Items in category       | Total | Adoption | Productivity | Livelihoods |
|---------------------------------|-------------------------|-------|----------|--------------|-------------|
| Publication type                | Peer-reviewed journal article | 51    | 42       | 10           | 12          |
|                                 | Book chapter            | 1     | 1        | 1            | 1           |
|                                 | Conference proceeding   | 8     | 6        | 3            | 2           |
|                                 | Report                  | 6     | 6        | 4            | 3           |
|                                 | Working paper           | 7     | 3        | 1            | 4           |
| Year of publication             | 2016–2019               | 15    | 10       | 3            | 7           |
|                                 | 2011–2015               | 21    | 19       | 7            | 6           |
|                                 | 2001–2010               | 28    | 24       | 6            | 8           |
|                                 | Before 2001             | 9     | 5        | 3            | 1           |
| Agro-ecological zone            | Mixed systems           | 53    | 41       | 12           | 15          |
|                                 | Agro-pastoral systems   | 10    | 9        | 2            | 2           |
|                                 | Pastoral systems        | 3     | 1        | 2            | 1           |
|                                 | Multiple systems        | 1     | 1        | 1            | 1           |
|                                 | Other                   | 2     | 2        | 1            |             |
|                                 | (Blank)                 | 4     | 4        | 2            | 2           |
| Regions                         | Horn of Africa          | 12    | 11       | 2            | 3           |
|                                 | East Africa             | 23    | 19       | 5            | 6           |
|                                 | Central Africa          | 1     | 1        |              |             |
|                                 | West Africa             | 7     | 5        | 2            | 1           |
|                                 | Southern Africa         | 5     | 5        | 2            | 1           |
|                                 | South Asia              | 6     | 4        | 1            | 2           |
|                                 | Southeast Asia          | 12    | 7        | 3            | 8           |
|                                 | East Asia               | 2     | 2        | 2            | 1           |
|                                 | Latin America           | 5     | 4        |              | 2           |
| Type of methods                 | Quantitative            | 45    | 40       | 14           | 13          |
|                                 | Qualitative             | 9     | 5        |              | 2           |
|                                 | Quantitative/qualitative| 19    | 13       | 5            | 7           |
| Duration of the experiment      | >20 years               | 3     | 1        | 1            | 2           |
|                                 | 11–20 years             | 4     | 4        | 1            | 1           |
|                                 | 1–5 years               | 22    | 16       | 6            | 8           |
|                                 | 6–10 years              | 8     | 6        | 3            | 5           |
|                                 | NA                      | 36    | 31       | 8            | 6           |
| Total                           |                        | 73    | 58       | 19           | 22          |
intricacies of ruminant feeding without paying sufficient attention to how such technologies fit into general farming practices or farmer objectives. Additionally, a number of studies were dropped as per the exclusion criteria because they focused on large-scale livestock production. Several studies from Latin America fell in this category, which is consistent with the fact that farms in Latin America and the Caribbean are generally larger than farms in other regions, including sub-Saharan Africa and Asia.

Second, among the few papers included in the final analysis, the majority only analysed the adoption of feed interventions, and only six studies additionally documented the productivity and livelihood impact pathways of the feed interventions. The funding of research to generate rigorous and relevant evidence of feed innovation outcomes and impacts has been restricted mainly to those development projects introducing such innovations. However, such development-project-linked research may not be able to analyse the whole pathway from adoption to animal and household impact and may have a strong likelihood of adoption, since few changes to farming practices are required in contrast to planted forages and forage trees.

Fourth, no clear conclusion emerged from comparing the effects of various feed-oriented interventions. Indeed, the ranges of change indicators presented are so large that meaningful comparisons are difficult. Several factors seem to have contributed to this. First, the intervention categories (that is, planted forages, agroforestry and crop residues) contain a wide variety of individual interventions with very different potentials for inducing change. For instance, introducing a new forage crop into a system without any prior forage cultivation can yield substantial improvements in productivity compared with the incremental effects of introducing a new variety of an established forage species. Second, the approaches to determine intervention impacts differ considerably between studies. Where a development project is focused on development impact (for instance, by creating an enabling environment for farmers to adopt or by targeting mainly high-potential beneficiaries), outcomes are likely to be greater than in an independent study aiming to determine how farmers benefit from a variety of interventions. An example of the former is presented by Roothaert and Kerridge, reporting a gross margin increase of 239% among project participants, whereas a study on various fodder shrubs in central Kenya was able to detect an income improvement of only 10% (ref. 11). Third, the time horizon considered by the reviewed studies varies greatly (Table 2). Most studies report changes only for the entire study period rather than average annual changes. Also, the rate of change brought about by feed interventions might not be constant. It is probable that a single intervention would generate change along an S-curve with only little evidence of change initially, followed by a period of considerable change, after which the rate would decrease. The reported rates may refer to very different periods within the change processes. Finally, the success of land-based interventions, such as those targeting feeds, is generally very site-specific, depending on biophysical features (such as rainfall or temperature) as well as on social characteristics (such as land prices or market access). The reviewed studies cover a wide range of such features and characteristics, from densely populated and humid Philippines and Vietnam to mountainous Nepal, showing increases in household income of 285% and 11%, respectively.

Finally, this scoping review has identified various factors driving or constraining the adoption of feed interventions, which can be grouped into three broad and inter-related categories. The first category refers to managing a sometimes-challenging technology, requiring certain skills on the part of the farmer as well as access to the technology, to extension and to training in its use. Second, the benefits of using a technology and its alignment with the farmer’s objectives must be perceived and valued by the farmer for adoption to occur. This is often an issue because feed is an intermediate technology in the livestock value chain, and the link between better feeding and financial benefits may not be easily perceived. Furthermore, livestock may be kept for a range of reasons other than the production of milk and meat, and the
This scoping review has shown that besides technical feed efficiency characteristics, various other factors enhance or constrain the adoption of improved feeds. On the basis of our analysis, we recommend the following:

- For ‘knowledge-intensive’ technologies, the capacity of local livestock keepers and the strength of the extension advice environment to support ongoing implementation should be considered. If these are limited, some re-evaluation of the technology options or a parallel effort to enhance the necessary capacity among local livestock keepers is needed.
- In planning development efforts for livestock feeding, the focus needs to be on small-scale, semicommercial farmers who have both the resources and the incentive to make the investments needed for feed technologies to succeed. Livestock keepers whose primary objectives for keeping livestock are not to produce milk and meat for the market need a different kind of support and are much less likely to invest in new feed technologies.
- The resource requirements for livestock feed options need careful consideration. If other uses for land and labour are more lucrative, livestock keepers are unlikely to invest in new feed options. This requires the whole farming system to be considered, as well as how livestock fit into overall livelihood strategies. In addition, unlike food crops, forage seed systems are underdeveloped in many regions (especially sub-Saharan Africa), with unclear demand and limited supply from the private sector. Public–private partnerships and investment may be needed to develop these supply chains and can be linked to local seed-producing entrepreneurs and collective groups.
- Decision makers and development agents should consider these factors and constraints in deciding when and where to target investments promoting these technologies. The conditions that favour feed technology adoption go far beyond biophysical suitability, extending to the social, economic and knowledge domains.

farmers’ primary objective may not be immediately obvious to well-meaning development agents. Third, the availability of the key resources of land and labour, and the trade-offs between them that the feed technology may impose, will limit or facilitate adoption, with adequate availability of both (particularly labour) generally having a positive effect. The trade-offs in certain contexts may mean that farmers can derive greater benefit from allocating land and labour to non-livestock activities, and this needs careful consideration when considering feed interventions.

The consideration of these adoption drivers and constraints is helpful for considering future approaches to enhancing livestock feed supply among poor livestock keepers. Too often, technologies have been promoted without systematically considering barriers to their uptake, whether target farmers have sufficient resources (both financial and human) to successfully implement them and whether the technologies make economic sense given the market conditions and the competing opportunities for the use of land and labour in target communities. Box 3 presents recommendations for researchers and development practitioners.

Methods

Evidence synthesis methodology and protocol preregistration. This scoping review was conducted following the PRISMA-ScR (Preferred Reporting for Items for Scoping Reviews) checklist. A protocol was registered in Open Science Framework on 5 June 2019 at https://osf.io/6ywht/.

Information sources, searches and citation management. A comprehensive search strategy was developed (by E.L. and E.E.) to identify all available research pertaining to the livelihoods of small-scale and agro-pastoral livestock keepers in LMICs in Africa, Asia and Latin America, in relation to the adoption or rejection of new feed technologies. The search terms included variations of the key concepts in the research question: improvement or conservation of crops; small-scale producers or pastoralists; LMICs in Africa, Asia or Latin America; innovation or adoption indicators. The comprehensiveness of the search strategy was ensured by including all known search-term synonyms and appropriate subject term searches, conducting a peer review of search strategy by expert librarians familiar with the discipline, and confirming the inclusion of eight seminal studies in the results set. See Supplementary Appendix A for the search strategy used for CAB Abstracts (accessed via the Clarivate Analytics platform).

On 5 June 2019, four bibliographic databases were searched. These included CAB Abstracts (Clarivate Analytics, 1910–present), Web of Science Core Collection (Clarivate Analytics, 1900–present), Scopus (Elsevier, 1970–present) and Dissertations and Theses Global (ProQuest, 1743–present). On the same day, 20 grey literature sources were searched, including Africa Theses and Dissertations, AgEcon Search, AGRIS, Campbell Collaboration, Cochrane Collaboration, COT take place in LMICs in Latin America, Africa or Asia; (4) the study does not consider improved feed options (introduced by an external entity or the farmer’s own experimentation); (5) the study considers only target populations in LMICs; and (6) the study is in English, French, Spanish or German.

In addition, studies were excluded if they met one or more of the following exclusion criteria: (1) the study focuses on a population of small-scale and agro-pastoral keepers of large and small ruminants; (2) the study is primary empirical research; (3) the explicit population focus is small-scale and agro-pastoral ruminant livestock keepers; (4) the study does not consider improved feed options (introduced by an external entity or the farmer’s own experimentation); (5) the study only considers industrial by-products and/or their effect on productivity, livelihoods or both; (6) the study area or focus includes target populations in LMICs; and (6) the study is in English, French, Spanish or German; and (7) the study considers only fish, pigs, poultry, camels, wild buffaloes, yaks, alpacas, guinea pigs (or caymus), bees, equines, rabbits or any wild animal.

Data extraction and analysis. A data extraction template was created on the basis of Barrett et al. and adapted to the scoping review requirements. The data extracted included the author(s), year of publication, type of paper, study location, intervention type, comparator (if any), duration of the intervention, study population and methodology; the outcome measures differentiated by adoption, effects on livestock productivity and effects on livelihoods; and important results in terms of drivers of adoption and potential for scaling. The template was tested by I.B. and A.D. before being finalized. Google forms were used to extract the data by I.B., A.D., N.T., D.C., E.J.R., S.S. and R.L. Conflicts were resolved by a third author as a tie-breaker. The data analysis tables were created and data processed by N.T., I.B. and E.J.R. Data were extracted from 51 peer-reviewed journal articles, 6 working papers published in conference proceedings, 7 working papers, 6 reports and 1 book chapter. The quality assessment was conducted on the 73 included papers using three criteria. The first one considered the quality of the study methodology (low versus high), the second assessed the justification of the methodology (low versus...
high) and the third criterion was an overall quality assessment with three levels (low, medium and high). Each paper was scored by two persons (D.C., A.D., I.B. and R.L.). The levels were first transformed into scores (high, 1; medium, 2; low, 3) and then averaged.

To better understand some of the underlying drivers of adoption of improved feed technologies, a subset of the final papers was selected for more detailed examination if they mentioned analysis of factors that either facilitated adoption or constrained adoption. Of the 73 papers in the full set, 25 met this criterion. Each of these papers was then re-examined by one researcher, and a set of adoption driver and constraints was identified; the papers were scored on whether they mentioned each adoption driver or constraint. Twelve different adoption drivers emerged, such as increased productivity and good access to markets. Nine constraining factors were also indicated across this set of papers, such as low perceived benefit of the technology and competition with other land uses.

Data availability
The data that support the findings of this study are available from the corresponding author upon request.

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Author contributions
E.L. and E.E. led the search process and contributed to the title screening and writing the manuscript. I.B. liaised with E.L. and E.E. on the search process, coordinated the paper screening, contributed to the screening at all stages, developed the data extraction template and contributed to the data extraction, data analysis and writing. S.S. identified the overall research question, contributed to the abstract and paper screening, and contributed to the data extraction and writing. A.D. supplied tropical livestock nutrition expertise, contributed to the screening at all stages and contributed to writing. D.C. and R.L. contributed to the screening at all stages and contributed to writing. E.J.R. contributed to the screening at all stages, data analysis and writing. N.T. contributed to the screening at some stages, led the data analysis and contributed to writing.

Competing interests
The authors declare no competing interests.

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Extended Data Fig. 1 | PRISMA flow diagram.