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Assessing farmer perceptions on livestock intensification and associated trade-offs using fuzzy cognitive maps; a study in mixed farming systems in the mid-hills of Nepal

Victoria Alomia-Hinojosa[1,2] | **Jeroen C. J. Groot**[1,3,4] | **Jens A. Andersson**[4,5] | **Erika N. Speelman**[6] | **Andrew J. McDonald**[7,8] | **Pablo Tittonell**[9,10]

[1]Farming Systems Ecology Group, Plant Sciences, Wageningen University, Wageningen, The Netherlands

[2]Colegio de Ciencias e Ingenierias, Ingenieria en Agronomía, Universidad San Francisco de Quito, Quito, Ecuador

[3]Development Impact Unit, Bioversity International, Maccarese (Fiumicino), Italy

[4]Sustainable Intensification Program, International Maize and Wheat Improvement Center (CIMMYT), Texcoco, Mexico

[5]Plant Production Systems, Plant Sciences, Wageningen University, Wageningen, The Netherlands

[6]Laboratory of Geo-information Science and Remote Sensing, Environmental Sciences, Wageningen University & Research, Wageningen, The Netherlands

[7]South Asia Regional Office, International Maize and Wheat Improvement Centre (CIMMYT), Kathmandu, Nepal

[8]Section of Soil and Crop Sciences, School of Integrative Plant Sciences, Ithaca, Cornell University, Ithaca, New York, USA

[9]Agroecology, Environment and Systems Group, Instituto de Investigaciones Forestales y Agropecuarias de Bariloche (IFAB), INTA-CONICET, San Carlos de Bariloche, Argentina

[10]Groningen Institute of Evolutionary Life Sciences, Groningen University, Groningen, The Netherlands

Correspondence
Victoria Alomia-Hinojosa, Colegio de Ciencias e Ingenierías, Universidad San Francisco de Quito, P.O. Box 170901, Quito, Ecuador.
Email: victoria.alomiahinojosa@gmail.com

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Abstract

Intensified livestock production is considered as a promising pathway for smallholder farmers. Nevertheless, this pathway may entail prohibitive investment requirements of labour, capital or trade-offs at farm level that preclude sustainable intensification. We used fuzzy cognitive mapping (FCM) to assess farmers' perceptions of changes in the farm household system resulting from adding livestock to their mixed farms. Farmers identified trade-offs between the increased income and farmyard manure production versus increases in labour requirements for fodder imports. Furthermore, a sensitivity analysis performed on the FCMs showed that an increase in milk market demand could have strong positive effects on livestock production and income. We conclude that FCM is a good tool to rapidly identify trade-offs and analyse perceptions of farmers which revealed that although they consider intensification a promising strategy, the perceived deepening of labour constraints and increasing dependency on fodder import makes a concurrent (sustainable) intensification of these farm systems unlikely.

KEYWORDS

decision-making, ex-ante methods, household farm systems analysis, intensification constraints, smallholder farmer

1 | INTRODUCTION

The consumption of meat, milk and eggs in low and middle-income countries (LMICs) has more than tripled over the past 30 years (Food and Agriculture Organization [FAO], 2018). In intensive crop-livestock systems in South Asia, livestock numbers are projected to increase significantly: cattle and buffalo from 150 to 200 million animals by 2030 and pigs and poultry by 40% in the same period (Herrero et al., 2010). Poultry meat together with milk are the main animal products projected to increase in consumption in South-Asia. Milk is already high at per capita level, 50% above the average for developing countries. (FAO, 2018).

In the smallholder intensive mixed farming systems that predominate in the mid-hill regions of Nepal, opportunities for expansion of crop production are limited due to their small farm size of less than 0.6 ha on average. Livestock intensification in these systems has the potential to contribute to food security and household income, and it represents a source of manure for increased food and fodder production (Alomia-Hinojosa et al., 2018; Ates et al., 2018; Ellis, 2000; Lemaire et al., 2014; Niehof, 2004; Pilbeam et al., 2000; Rufino et al., 2009; Salmon et al., 2018). The integration of livestock and crop production can create synergies, such as better regulation of biogeochemical cycles, more diversified landscapes that favour habitats and trophic networks, and greater farm system flexibility to cope with potential socio-economic and climate change hazards (Lemaire et al., 2014). Such synergies could offer opportunities to raise productivity and resource use efficiency both for households and regions (Herrero et al., 2010; Tittonell et al., 2015). In this regard, increased livestock production within crop-livestock systems may be a suitable intensification pathway for smallholder farmers in Nepal.

Increasing livestock production in mixed farming systems commonly entails a substantial reconfiguration of farming practices related to the use of resources such as land, and nutrients in animal feed and manure. Furthermore, competition of biomass for food and feed and increased labour demands are likely to occur under livestock intensification (Erenstein et al., 2015). This could particularly occur in the mid-hills regions of Nepal where farms have already high livestock densities and are highly dependent on fodder cut from the forested hills (Alomia-Hinojosa et al., 2018; Pilbeam et al., 2000). Such challenges of farm adjustments depend on socio-economic and biophysical specificities and can therefore differ greatly between regions and between farm types. Furthermore, external drivers such as milk market demand have also an effect on livestock production and associated trade-offs. These drivers operating at multiple levels together with systems management influence the agroecosystems dynamics (Valbuena et al., 2015).

Farmer perceptions are key to understand the functioning of the farm and the limitations associated with farm changes and the resulting decision-making of diverse types of farmers. The decision making of farmers will affect the extent to which livestock intensification becomes part of livelihood strategies. Understanding such perceptions of different types of farmers on intensification strategies can inform development projects (Alomia-Hinojosa et al., 2018) and policy making.

Cognitive mapping approaches have been used to identify people's perceptions of complex social and socio-ecological systems (Özesmi & Özesmi, 2004), as well as to analyse their decision making (Vanwindekens et al., 2013). By using fuzzy cognitive mapping (FCM), information on perceptions, behaviour and decision-making in complex situations can be obtained quickly and easily even with small samples (Özesmi & Özesmi, 2004). FCM has been applied in agricultural system analysis (Ditzler et al., 2018) with a multitude of objectives such as: to explore farmers' perceptions about pesticides (Popper et al., 1996); to understand environmental management measures (Ortolani et al., 2010); to describe practices in agroecosystems (Isaac et al., 2009); to understand impact of agricultural systems on the environment (Özesmi & Özesmi, 2004); to evaluate the sustainability of agroecosystems (Fairweather & Hunt, 2011; Rajaram & Das, 2010); to cluster farm types or groups as a function of certain indicator variables (Mathevet et al., 2011; Ortolani et al., 2010; Özesmi & Özesmi, 2004; Vanwindekens et al., 2013); and to explore vulnerabilities of livelihoods to identified hazards (Murungweni et al., 2011). In agriculture, FCM is considered a useful tool to represent farmer's vision on their practices and potentially improve the debate on the sustainability of farming systems (Fairweather & Hunt, 2011).

In this study, we use FCM to explore the perception of individual farmers on the presence and importance of trade-offs associated with livestock intensification. We compare perceptions about livestock intensification of differently resource-endowed households in two contrasting localities in the mid-hills region of Nepal. In addition, we analyse the interactions among farm system components, that is, crops, animals, household, as perceived by farmers by exploring their potential responses to changes in external drivers. Our study is unique in that it uses a participatory approach, by allowing individual farmers to express their understanding of the system by developing FCM maps in which they visualize and describe the trade-offs of livestock intensification and the effects on the whole farm system.

2 | MATERIALS AND METHODS

2.1 | Description of the study sites

The study was conducted in two mid-hill regions of Nepal: the Palpa district is located in the Western region and the Dadeldhura district located Far-Western region. Palpa and Dadeldhura are situated at 1300 and 1500 m above sea level, respectively. The soils in both districts are chromic cambiosols (Dijkshoorn & Huting, 2009). The soil texture in Palpa is predominantly loam, and loam to silty in Dadeldhura. The climate as described by the Koppen classification in the mid-hills is mostly subtropical to temperate (Department of Hydrology and Meteorology of Nepal, 2015). The two districts have a dry winter and a summer monsoon. The wet summers (June–September) have an average precipitation of 1052 mm in Palpa and 990 mm in Dadeldhura, whereas in the dry winters (December–March), the precipitation is slightly lower in Palpa (228 mm) than in Dadeldhura (349 mm) (Department of Hydrology and Meteorology of Nepal, 2015).

In both mid-hill districts, there are two main cropping seasons. In Palpa, the main crop grown in summer is maize (*Zea mays*) usually mixed with legumes such as rice bean (*Vigna umbellata*), soybean (*Glycine max*) and cowpea (*Vigna unguiculata*), finger millet (*Eleusine coracana*) and/or cucurbits. In winter prevails mustard (*Brassica nigra*) mixed with chickpea (*Cicer arietinum*) or lentil (*Lens culinaris*). In Dadeldhura, both maize and upland rice are the main cereals in summer. Maize is mixed with legumes such as soybean, cucurbits and finger millet. In the winter, wheat (Triticum aestivum) is the main crop. From January to April–May most of the fields are fallow. In the case of a cropping in a third season (spring), vegetables are cultivated by farmers with access to irrigation. Most of the crops are used for home consumption, while vegetables in both sites and soybean in Dadeldhura are used as cash crops. Cereals, particularly maize, are dual purpose used both for feed and food. On average, 90% of maize grain in Palpa and 40% in Dadeldhura are used for feed whereas the rest is used for household consumption. All the studied farms raised some sort of livestock such as milking cattle, buffaloes, goats, or chicken. In Palpa the average number of tropical livestock units (TLU) is 7, while in Dadeldhura farms own on average 5 TLU. One cow with an estimated average live weight of 250 kg was defined as 1 TLU; further equivalent conversion factors were established for the rest of the animal species (Jahnke, 1982). In Palpa, milking cows predominate, whereas in Dadeldhura, milk is obtained mainly from buffaloes. One to three goats are typical raised per farm (Alomia-Hinojosa et al., 2020).

2.2 | Farmer diversity

The typologies were constructed and presented in a previous study by Alomia-Hinojosa et al. (2020). A total of 100 households in Palpa ($n = 50$) and Dadeldhura ($n = 50$) were surveyed. For each district, a farm typology was built using multivariate analysis: a principal component analysis (PCA) was performed to identify non-correlated explanatory variables, followed by a hierarchical clustering (HC) to group the farms. The clustering algorithm finds the most homogeneous groups possible, minimizing the intragroup heterogeneity and maximizing inter-group heterogeneity (Alvarez et al., 2018).

The significant socio-economic differences between Palpa and Dadeldhura and between farm types are mainly in yearly income, source of income and number of (TLU) per farm while the number of household members and the size of productive land are comparable (Table 1). The variables used for the typology construction were: number of household members, yearly income, productive land holding, labour, number of TLU and months of food self-sufficiency (Alomia-Hinojosa et al., 2020). Three farm types were identified in each district. Both independent typologies show similar relative differences across farm households in terms of resource endowment: from farms with lower (LRE), to medium (MRE) to higher (HRE) resources endowment (Table S1).

The LRE and MRE farmers in both sites had smaller productive land size (averages between 0.18 and 0.33 ha) than the HRE farmers that cultivate on average 0.65 to 0.72 ha. The yearly income varied among the types being the highest for the HRE in Palpa. Interestingly, the percentage of income from the farm activities was also the highest for the HRE and lowest for the LRE in both sites, contrary to the common belief in the region, that HRE farmers obtain highest percentage of their income from off-farm activities. In Palpa the largest proportion of income for HRE and MRE was derived from livestock products, while in Dadeldhura the first source of income

TABLE 1 Characteristics of farms types with different resource endowment types, that is, low (LRE), medium (MRE) and high (HRE), in two districts (Palpa and Dadeldhura) in the mid-hills of Nepal

	Palpa			Dadeldhura		
Farm characteristic	**LRE**	**MRE**	**HRE**	**LRE**	**MRE**	**HRE**
Number of household members	4	6	6	7	4	5
Annual income (USD)	1369	2117	6957	703	894	2557
Area of productive land (ha)	0.18	0.29	0.65	0.27	0.33	0.72
Labour force (persons)	2	3	4	3	2	3
Livestock per farm (TLU)	2.27	5.49	12.08	4.11	4.46	4.98
Food self-sufficiency (months)	5	8	11	4	5	10
Income derived from farm (%)	25	33	71	23	24	38

Note: USD = United States Dollar; TLU = tropical livestock units; ha = hectares. The values represent the average of each farm type.

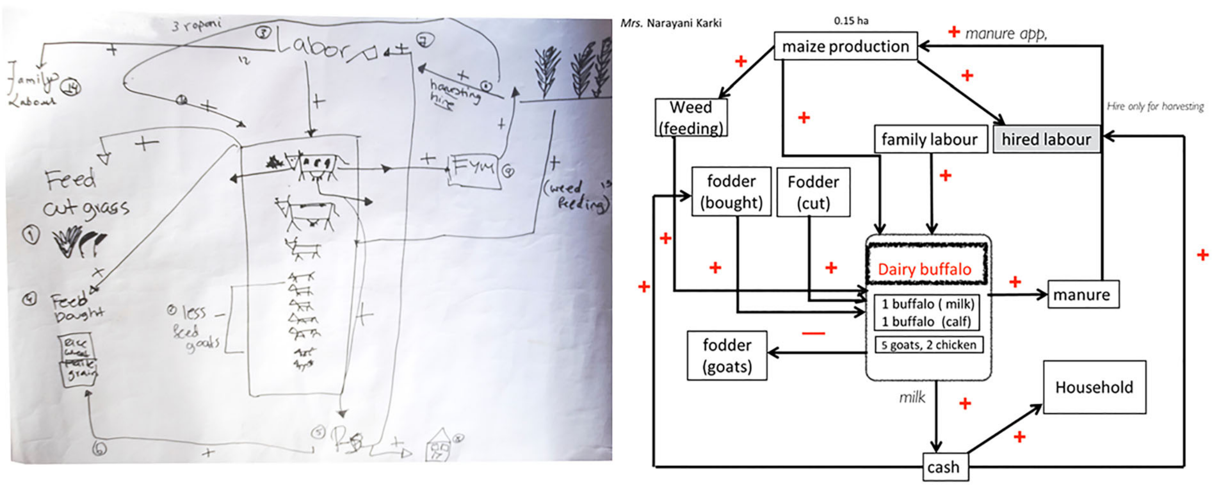

FIGURE 1 Example of a farm system map constructed with farmers as drawn in the participatory session (left) and conceptual representation (right). The maps reflect farmer-perceived changes that would occur after adding one livestock unit to the farm [Colour figure can be viewed at wileyonlinelibrary.com]

were off-farm activities from remittances or jobs outside the farm. The quantity of livestock was on average nine TLU in the HRE farms and three in the LRE. In general farms in Dadeldhura have buffaloes and goats for milk production, while cows predominate in Palpa. For LRE farms the herd mainly combined one to two chicken, two to four goats, and one buffalo, while HRE herds were composed of up to 10 milking cows and 14 goats. HRE farms in Palpa have the highest number of livestock mainly dairy cows up to 17 TLU. The labour force on average was larger on the HRE farms with up to four persons and two persons for the LRE farms.

2.3 | Constructing farm system maps with farmers

We developed cognitive maps of individual farm systems, in 2016, with focus on livestock intensification with 62 farmers (32 farms in Palpa and 30 in Dadeldhura; ~10 per resource endowment type: low [LRE], medium [MRE] and high [HRE] in each district). The drawings of these maps were guided by the farm household head (approximately 47% of them were women in Palpa and 76% were women in Dadeldhura) using flip chart paper, and were used to discuss the perceived consequences of intensified livestock production at farm level. Each farm system map started with the current endowments of the farm in terms of land, labour and livestock resources. Then, the discussion on the consequences of intensification by adding one dairy cow or buffalo to the farm was started (see Figure 1 for an example) Farmers were asked the question: “What does this mean for your farm?” The farmers described the plausible changes that their farming system would undergo in the order of importance as assigned by the farmer. Although the discussion started asking the farmers about changes in their farm system after adding a cow or a buffalo, farmers were allowed to mention any other type of livestock. Farmers were asked to develop maps that depicted the relevant components of the farm system as text boxes and the relations among components (positive or negative influences) as arrows. Relative strengths of the relations were not indicated.

2.4 | Fuzzy cognitive mapping

FCM is a semiquantitative knowledge-driven modelling technique (Ditzler et al., 2018; Fairweather, 2010; Vanwindekens et al., 2014) composed of a number of concepts (represented by boxes) with positive or negative interrelations that are denoted by arrows with weights (Kok, 2009). The FCM is based on key concepts that are defined by one or more constructors and that represent important processes, agents and events within the system that is analysed. The interrelations are perceived causal relationships among these concepts (Özesmi & Özesmi, 2004). These relationships can be either positive or negative and have a weight that ranges commonly between −1 and 1 (Kok, 2009).

2.4.1 | FCMs of individual farmer perceptions

The system maps of individual farms were translated into FCMs. The entities and processes on the farm relevant to crop and livestock production as listed by the farmers were used as FCM concepts. The original farmer-specified interrelations were used among the concepts, in which the weights were quantified by assigning a value of 1 for a positive effect and −1 for a negative effect. We counted the number of concepts (N_C) and relations (N_R) and calculated the density (D) by dividing N_R by the maximum number of connections possible relations among concepts (Özesmi & Özesmi, 2004). For individual concepts we calculated (Özesmi & Özesmi, 2004):

- Indegree (I_C), which is the sum of absolute weights (−1; +1) of interrelations entering a concept, shows the cumulative strengths of relations entering a concept.
- Outdegree (O_C), calculated as the sum of absolute weights of interrelations exiting the concept, shows the cumulative strengths of relations exiting a concept.
- Centrality (X_C) is the sum of I_C and O_C. It shows how connected the concept is to other concepts and what the cumulative strength of these connections is.

Additionally, we defined the three different types of concepts: transmitter ($O_C > 0$ and $I_C = 0$), receiver ($I_C > 0$ and $O_C = 0$), and ordinary concepts ($I_C > 0$ and $O_C > 0$) (Bougon et al., 1977; Eden et al., 1992; Harary et al., 1965; Özesmi & Özesmi, 2004). Since transmitters have an influence on the system, but are not affected by other concepts in the system, we denote these concepts as "external drivers."

2.4.2 | Aggregate cognitive maps

With the aim of analysing similarities and patterns among districts and farm types, we developed aggregated cognitive maps using an approach modified from the Cognitive Mapping Approach for Analyzing Actor's Systems of Practices (CMASOP) (Vanwindekens et al., 2014), which involves building aggregate cognitive maps by combining FCMs that have been constructed by individuals. The FCMs of individual farmers were grouped per district and per resource endowment type. We combined concepts and interrelations mentioned by farmers, and calculated the average weights resulting in aggregate cognitive maps (ACMs) using the +1 and −1 weights. Thus, we assumed that the number of times that a concept was mentioned by farmers reflected the importance of relations. Therefore, the weights in the ACM were calculated as the percentage of maps in which the influence was mentioned. Weights were derived by scaling the percentage-weights to a range of 0.1 to 0.7 for positive influences and −0.7 to −0.1 for negative effects.

2.4.3 | Matrix multiplications

We performed iterative matrix multiplications on the ACMs to determine the equilibrium state values of the concepts (Kok, 2009). The matrix contains the values of all relationships between concepts, usually between −1 and +1, whereas the state value of the concept presents the value of the concept, usually between 0 and 1 (Kok, 2009). A balanced FCM will lead to equilibrium values for the concept state values.

The calculation of a new state value can be repeated infinitely during which, all concepts can stabilize at a constant value. In theory, the procedure should be repeated at least $2 \times n$ (total number of concepts) times to allow for all indirect effects to expend. While in practice, the pattern can usually be determined after 20–30 iterations, although total stabilization can take more than 100 iterations (Kok, 2009).

The multiplication function used in this study was independent on the current state of the concept equation 1 (Kok, 2009; Stach et al., 2005). In Equation 1, t is the iteration number, $A_i(t)$ and $A_i(t+1)$ are the state values of concept i at iterations t and $t+1$, and w_{ji} is the weight of the relation between concepts j and i.

$$A_i(t+1) = \left(\sum_{\substack{j \neq i \\ j=1}}^{N} w_{ji} \cdot A_j(t) \right). \quad (1)$$

2.4.4 | Sensitivity analysis

The results of the matrix calculations on the ACMs were used for a sensitivity analysis of changes caused by three potential drivers that were proposed as external processes that could affect farm activities and configuration as represented in the ACMs (cf. Kok, 2009):

- Livestock intensification (increase in demand for animal products): caused by changed diet preferences for more livestock products and better market access for farmers, which would have a positive impact on livestock numbers per farm.
- Losses of manure: due to adverse conditions that cause higher manure loss rates. This would reduce the availability of manure on the farm and generate a negative effect on soil fertilization and crop productivity.
- Out-migration: part of the labour population could leave farms to urban areas or labour opportunities abroad which would negatively affect the available labour.

Drivers are concepts that influence but are not influenced by other concepts. The drivers represent external influences in the system. The driver of out-migration corresponded to a common trend occurring in both mid-hills provoking labour shortage in farms in both districts. The nutrient losses were added due to evidence of nutrient dissipations/losses of N in the studied farms (Alomia-Hinojosa et al., 2020).

The target variables for which we determined impact of the external drivers in the sensitivity analysis were "livestock," "family labour," "crop production" (maize, cereal or vegetables) and "farm income (cash)." We used the Winding Stairs algorithm (Chan et al., 2000; Jansen et al., 1994). It allows to quantify the strength of the influence of each driver on target variables (cf. regression coefficient) and the total sensitivity index (TSI) (Chan et al., 2000), which measures the contribution of an input factor (driver) to the total model output variation (Chan et al., 2000) and is equivalent to the r^2 of a regression.

3 | RESULTS

3.1 | Farm systems maps

During the farm system mapping of the impact of adding one dairy cow or buffalo to the farm, the farmers in both Palpa and Dadeldhura mentioned the additional requirements for feed and labour as the most important consequences, rather than the additional benefits of increased income, manure availability and crop production (Table 2). The additional fodder needed to feed the added cow or buffalo would be collected from road-sides and other open or common resources such as forest, or would be purchased. Fodder collection was mainly done by women. Only ∼30% of the farmers mentioned the potential positive impact of livestock intensification on income as either a first or second consequence. Extra manure production and higher cereal production were never mentioned as the first consequence, and by less than 25% of the farmers as a second effect (Table 2).

The extra manure obtained from the additional TLU would be applied to all the crops, especially cereals:

TABLE 2 The most important consequences (concepts) of increasing the livestock number with one TLU on farms in mixed systems in the mid-hills of Nepal as perceived by the farmers

	Palpa		Dadeldhura	
Perceived consequence	**Mentioned first (%)**	**Mentioned second (%)**	**Mentioned first (%)**	**Mentioned second (%)**
Have to collect or buy extra fodder	47	31	45	34
Increased labour requirement	38	31	24	24
Extra income for the household	13	16	24	3
Extra farm yard manure production	-	16	-	24
Increase in cereal production	-	-	-	13
Others	3	6	6	3

Note: Importance is expressed as the percentage of farmers mentioning consequences as first and second in farm systems mapping.

maize in Palpa and maize, rice and wheat in Dadeldhura. As a consequence, extra feed for livestock would be obtained from crop residues. But as a trade-off, more labour will be needed for crop maintenance, especially for weeding. Few farmers mentioned that if cereal production would increase they would purchase or collect less fodder. During the farm system map construction, the majority of farmers expressed an interest to increase livestock on their farms, but Palpa farmers preferred dairy cows and buffaloes, whereas in Dadeldhura, dairy buffaloes and goats were preferred. Furthermore, two farmers in this district declined to add a cow or a buffalo but instead chose 100 chicken. Irrespective of the endowment level, farmers were not inclined to make additional investments in (maize) fodder production and associated agronomic activities such as line planting, increasing the plant density, more meticulous weeding and investing in seeds. All resource endowment types implied an increase in labour as the first perceived consequence of adding an extra dairy animal. In Palpa, LRE farmers mentioned the increase of hired/family labour, whereas MRE and LRE mentioned the need to collect fodder (family labour) and the need to purchase extra fodder as the first consequence. Similarly, in Dadeldhura, all resource types mentioned the collection or purchase of extra fodder as the first consequence of adding an extra dairy animal on their farms (Table S2).

3.2 | Fuzzy cognitive mapping

3.2.1 | FCMs of individual farmer perceptions

The FCMs derived from the farm system maps contained a larger number of concepts (N_C) and relations (N_R) in Palpa than in Dadeldhura (Table 3). The LRE farmers from both sites mentioned a smaller number of concepts and relations, but D was comparable between resource endowment types and districts (Table 3). The ratio between receiver and transmitter concepts was considerably higher in the farms in Dadeldhura than in Palpa (Table 3).

The concept with the highest centrality in both sites was "Livestock," which represented the dairy cows or buffaloes on the farm. This concept was the original starting point for the farm systems mapping. In Palpa the second variable with highest centrality was "Cash/income" while lowest centrality was "Household consumption." In Dadeldhura, the second highest centrality was "Crop production" in all the types and the concepts with lowest centrality were "Family labour" and "Hired labour."

3.2.2 | Aggregate cognitive maps

The ACMs were the result of combining individual FCMs for each resource endowment type per district (Figure 2). In the ACMs, the role of purchased feeds and on-farm produced residues were included as important relations to support livestock intensification. The relations between manure production from livestock and its positive effects on productivity of maize (Palpa) and cereals and vegetables (Dadeldhura) were prominent in the ACMs of LRE as well as MRE and HRE farmers (Figure 2). Only a limited contribution of livestock to household nutrition was considered.

The quantification of the dynamics of the state values of the four target concepts in the ACMs for the different types of resource endowment farms in the different districts (six farms), stabilized after ~20 iterations of matrix multiplications (Figure 3). We analysed the sensitivity of these values after 100 iterations to the variations in the sensitivity analysis.

3.3 | Sensitivity analysis in the ACMs

The sensitivity analysis shows that according to the perception of the farmers, there would be strong effects of intensification on livestock production and farm income (Figure 4a), whereas out-migration would lead to reduced livestock production and farm income (Figure 4b). Livestock and nutrient losses were positively related (Figure 4c). These trends were strongest for the MRE

TABLE 3 Metrics of FCMs derived from farm system maps created by farmers with different endowment levels, that is, low (LRE), medium (MRE) and high (HRE), in two districts (Palpa and Dadeldhura) in the mid-hills of Nepal

	Palpa			Dadeldhura		
Metric	**LRE**	**MRE**	**HRE**	**LRE**	**MRE**	**HRE**
Density (D)	0.140	0.131	0.135	0.144	0.137	0.140
Number of concepts (N_C)	9.0	9.5	9.8	7.8	8.6	8.6
Number of relations (N_R)	11.1	11.7	12.5	8.6	9.6	9.8
Receiver/transmitter ratio	0.8	0.8	1.1	2.1	1.4	1.3

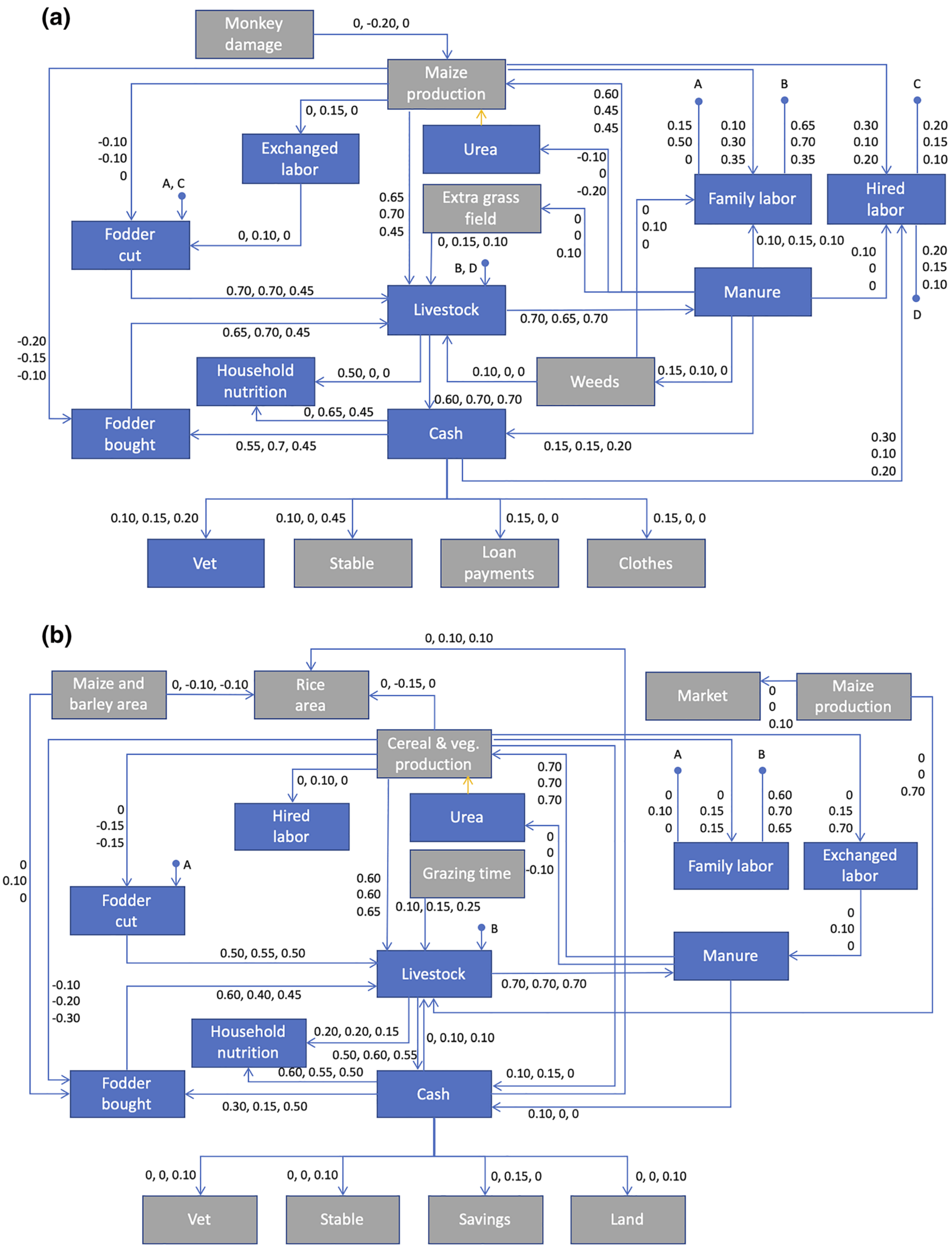

FIGURE 2 Aggregate cognitive maps for the perception of livestock intensification on farms of three resource endowment types in the districts of Palpa (a) and Dadeldhura (b) in Nepal. The three numbers per arrow represent the weights per RE type in the order: LRE, MRE and HRE. The colours of the boxes indicate whether a concept was mentioned by all farmers (blue) or by only a part of the farmers (grey) per district [Colour figure can be viewed at wileyonlinelibrary.com]

farm in Palpa. Similarly, the TSI indicated that the family labour is strongly affected by the driver of out-migration in all farm types, whereas crop production is affected by nutrient losses. Livestock intensification would lead to responses of livestock, crop production and farm income (Figure 4d–f).

4 | DISCUSSION

Through our participatory research, we were able to rapidly identify trade-offs and perceptions towards intensification together with farmers. It allowed us to understand that differently endowed farmers in terms of resources

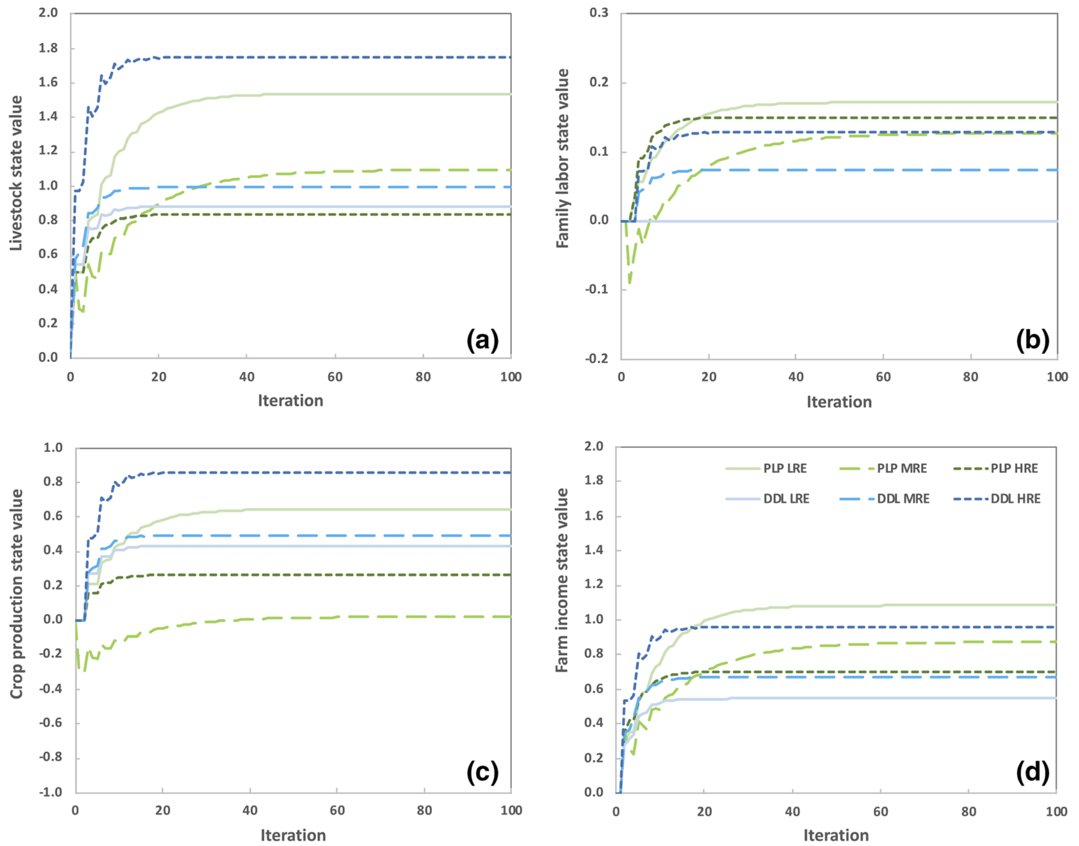

FIGURE 3 Dynamics of the state values of the four target concepts for the six farm categories. The dynamics stabilize after 100 iterations [Colour figure can be viewed at wileyonlinelibrary.com]

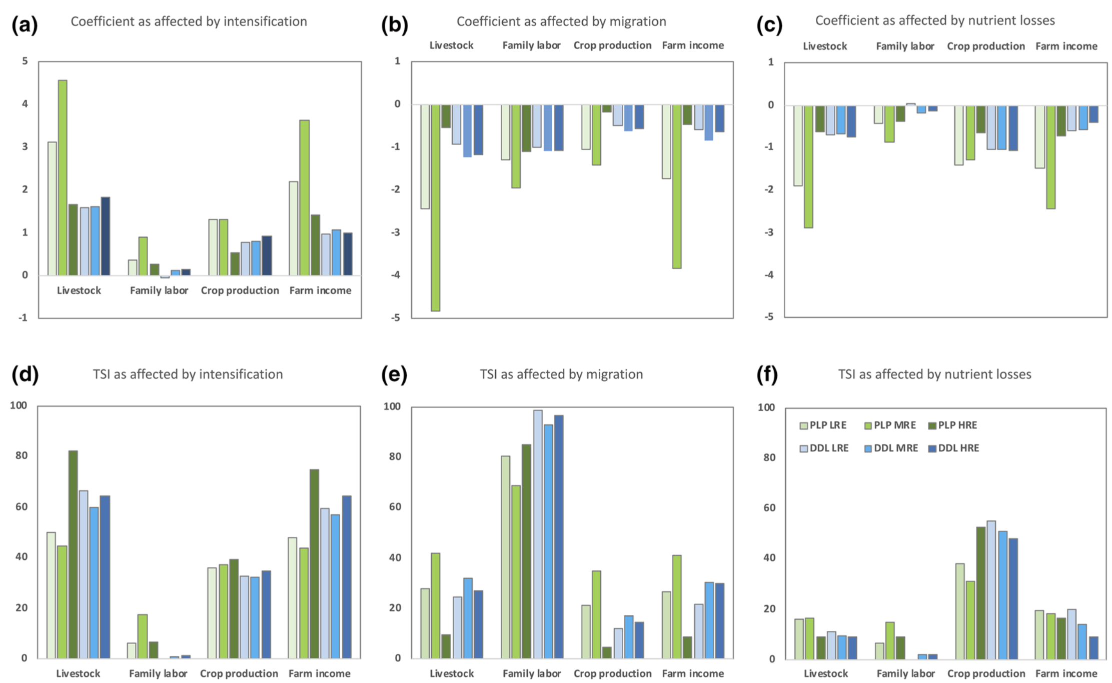

FIGURE 4 Result of the sensitivity analysis of drivers on ACMs: impact of variation in drivers intensification, migration, nutrient losses on variables: livestock, family labour, crop production and farm income expressed as coefficient (a–c) and TSI (d–f). The coefficient indicates the strength of the influence of the driver on the variable, while the TSI indicates the relative importance of the three drivers in influencing the variables [Colour figure can be viewed at wileyonlinelibrary.com]

and capital endowment faced similar trade-offs and constraints and therefore were not inclined to make additional investments in on-farm fodder production such as maize (used both for food and feed), and the associated crop management activities. Farmers perceived on-farm fodder production to be insufficient to bridge the widening fodder gap resulting from keeping additional livestock. In other words, intensification of dairy livestock production would not trigger the intensification of crop production.

Most of the farmers did not immediately think in economic terms at the system level. This was showed by farmers mentioning that income was not the first effect of adding a dairy cow into their systems. It was identified that farmers did not fully relate how productivity enhancement of fodder (maize) might lead to more returns at the farm level through increased milk production.

The prospects of intensification are restricted to farmers that have the capacity of investment and access to market or to collection centres, such as in some cases in Palpa. The increased labour demand was a factor consistently mentioned by farmers as the main trade-off associated with livestock intensification, rather than the additional benefits of extra income and manure that are normally associated with livestock.

The analysis of the FCM confirmed the differences in complexity of farm systems between districts. Although the density (D) of the networks was comparable in both districts, the numbers of both concepts and connections depicted in the maps were higher in Palpa than in Dadeldhura indicating that farmers in Palpa might perceive more opportunities available to change farm practices (cf. Özesmi & Özesmi, 2004) and their consequences for livestock intensification. The ratio between receiver and transmitter concepts was considerably higher in the farms in Dadeldhura than the ones in Palpa. This ratio shows (Özesmi & Özesmi, 2004) that farm maps in Dadeldhura were more complex than those in Palpa which means that farmers in Dadeldhura considered more implications that could result from adjustments of their farm system. In addition, in Dadeldhura there was more farm diversification due to a larger number of cultivated crops and livestock types, in contrast to the farms in Palpa that were more specialized. It was expected that the highest concept centrality was for livestock as it was the initial concept when drawing the cognitive maps. However, the second highest centrality differed among districts. *Income (cash)* was mentioned in Palpa and *crop production* in Dadeldhura, which gives insight on the different priorities in each district. Most of the farms in Dadeldhura are subsistence-oriented while farms in Palpa generated income through trading. Further explanation is given by the perception of the household head. In Palpa, 47% were women, whereas almost 80% were women in Dadeldhura. Women in Dadeldhura take the lead in farm production because of the seasonal or permanent migration of their husbands. Women perception might relate to the increase of labour caused by additional crop production to cover feed requirements.

FCM is often used to analyse systems representation of perceptions of multiple stakeholders or stakeholder groups for comparative purposes (Ditzler et al., 2018; Pacilly et al., 2016). The novelty of our research is that maps were drawn directly on the farm with the farmers, the main actors. This approach was useful to model diverse drivers and farmer motivations (Vanwindekens et al., 2014) and to compare farmers from different districts and livelihood objectives. Furthermore, through graphic theory (matrix algebra tools) it was possible to analyse the structure of the system which represents its overall behaviour in contrast to the solely sum of units (Özesmi & Özesmi, 2004). A limitation of the approach is the potential interviewer effect when guiding the mapping process which can potentially produce errors in indicator quantification. We aimed at minimizing errors with the relative large number of interviewees and by conducting additional discussions with farmers inside and outside the population of our study to validate our results. Our study reinforced the evidence that farmers can create maps and represent the character of their farm systems (Fairweather & Hunt, 2011), and how cognitive mapping can contribute to understand farmers systems reasoning and local knowledge which could benefit the management and performance of the farm (Fairweather & Hunt, 2011; Garini et al., 2017; Isaac et al., 2009).

Through this research, the knowledge about the trade-offs around livestock intensification in land constrained hill ecosystems was better comprehended by obtaining information of trade-offs directly from farmers. Including farmers diversity is essential when analysing the windows of opportunities for farmers (Tittonell et al., 2015). However, although we showed farm structural differences between districts, there seemed to be generalized perceptions of these trade-offs around livestock intensification regardless the resource endowment. The trade-offs and perceived negative consequences of increasing livestock explained the low rates of adoption of measures and technologies for livestock intensification in the mid-hills regions of Nepal (Alomia-Hinojosa et al., 2018; Pilbeam et al., 2000). This knowledge can contribute and inform both development projects and policymakers.

Livestock intensification might require higher investments to purchase extra feed, which limits livestock intensification for the majority of farmers, particularly the low and medium resource endowed. For these farmers, increasing one cow might have stronger impact than for the high resource endowment types with large number of TLU, for example, Palpa 17 TLU. In addition, the fodder available on or off farm does not cover the already high livestock density in the mid-hills agroecosystems, this goes in line with the perceptions of farmers indicating that increasing on-farm fodder production would be possible but not enough to feed an extra animal. Finally, increasing crop/fodder production in the mid-hills is limited by the small size of farms, which explains why farmers did not see clear connections or synergies between on-farm fodder production and livestock. Although demand for animal products would trigger livestock production and farmers consider intensification a promising strategy for income generation, the constraints of intensification make a concurrent (sustainable) intensification of these mixed farms' cropping systems unlikely. New strategies optimizing crop-livestock integration with existing farm resources are needed to support these systems.

5 | CONCLUSIONS

This research shows the capacity of using FCM to rapidly identify trade-offs in intensification together with farmers. FCM was proved as a good tool to analyse qualitative data to reveal perceptions of farmers. Moreover, it allowed the exploration of the influence of potential drivers to the perceived farm's concepts.

Farmers in the different regions and of different resource endowment types perceived increasing livestock density as a promising pathway for intensification and income generation. Livestock intensification is also enhanced by livestock demand. Yet, farmers of contrasting types (differing in endowment and complexity of farm configuration, resource allocation and management) perceived that livestock intensification can deepen the labour constraint and the dependency of external imports hence the realization of livestock intensification pathway and the adoption of associated practices and technologies could be strongly affected.

Furthermore, livestock intensification does not necessarily have the potential to trigger intensification of crop production in the studied sites as most of the farmers were not inclined to make additional investments in (maize) fodder production as they perceived these as insufficient to bridge the widening feed gap resulting from additional livestock. This can be attributed to perception of higher labour demand to increase on-farm production, which is enhanced by the high out-migration in the region, but also the lack of farmer's perception of how fodder (maize) productivity enhancement may lead to more income through increased milk production. Therefore, additional quantitative farm-level assessments of trade-offs and synergies are needed for smallholder mixed systems in the mid-hills of Nepal.

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DATA AVAILABILITY STATEMENT

The main data used in this manuscript are available in the public repository: fighshare.com. The links are as follows: https://doi.org/10.6084/m9.figshare.16640470, https://doi.org/10.6084/m9.figshare.16640461. The corresponding author authorize the publication of these data with the appropriate attribution and citation.

ORCID

Victoria Alomia-Hinojosa https://orcid.org/0000-0002-8561-8082

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