**Hermann Eiselen-Wissenschaftspreisträgerin 2022**

**Hermann Eiselen-Science Award Winner 2022**

**Marion Reichenbach "Dairy production in an urbanizing environment. A system approach in Bengaluru, lndia", University of Kassel, 2020**


Summary

An urbanizing environment typically dichotomizes itself into agricultural production oriented rural areas versus consumption-oriented urban areas, between which the flow of agricultural goods and services is a major rural-urban linkage (Figure 1). This flow is impacted by the social feedback of urban consumption patterns: it defines what is produced in rural areas, how much but also how. Production and consumption are also linked by an ecological feedback, that is the effect that the use of resource for agricultural production has on the source of the change, namely the consumers. Such a set forms a social-ecological system (SES). When linkages between SES components are tight, the local equilibrium between resource use and consumption is preserved in a "green-loop". Trends of agricultural intensification and market integration in rural areas due to growing urban demand increase a risk of failure of the ecological feedback between rural and urban areas, which shifts the SES towards a "red-loop". The latter is an unsustainable equilibrium as urban consumption outgrows local resources. By applying the SES framework to the topic of dairy production in an urbanizing environment, the role of the dairy producer thus changes from supplier to crucial link between society and environment for a sustainable use of resources.


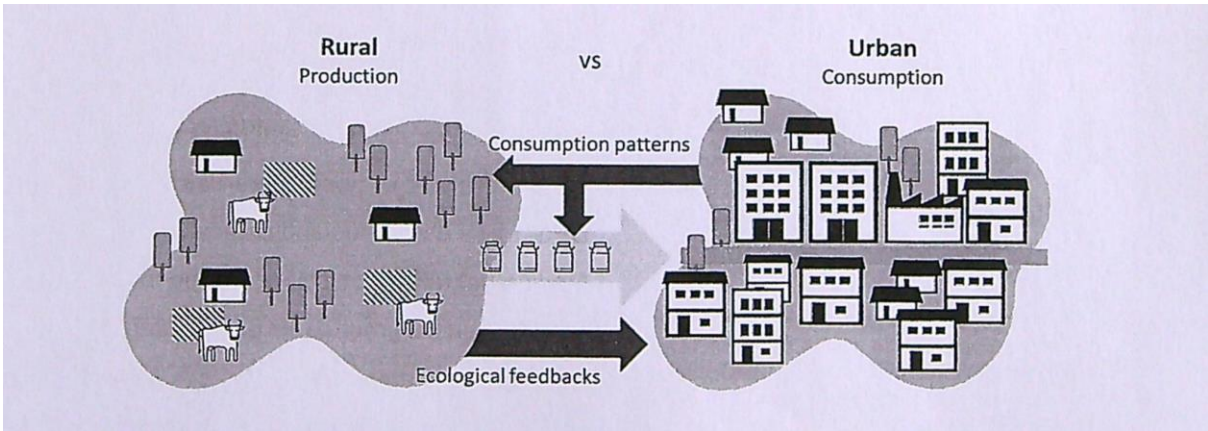


Figure 1 The social-ecological system of dairy supply and demand across a rural-urban interface and the different linkages between its components.

India is currently one of the fastest urbanizing countries and its dairy sector, the largest in the world, supports the livelihoods of about 70 million households. In a country where 40% of the population is vegetarian, dairy is a major source of animal protein. The current impacts of urbanization on dairy production are however neither assessed in terms of shifts in resources availability and use by dairy producers, structural change in the dairy sector nor in terms of the

increasing complexity of the social-ecological system that centers around dairy producers. The present study aims i) to provide deeper insights into the impacts of urbanization on dairy production, taking as case study the dairy sector of the Indian megacity of Bengaluru, which is one of the fastest growing cities in India and has now more than 10 million inhabitants; ii) to apply the SES framework to our case study to enlarge the discussion on food systems' sustainability by considering dairy producers as the crucial link between society and environment. The present study first focuses on identifying and characterizing the dairy production systems (DPS) that coexist in the rural-urban interface of Bengaluru, while highlighting potential social-ecological linkages between its components (Chapter 2; Figure 2). In a second step, the present study focuses on quantifying the impacts of distinct dairy production strategies in terms of resources use efficiency, namely feed conversion efficiency (Chapter 3), and global environmental impact, namely the emission intensity of greenhouse gasses (Chapter 4), in relation to the spatial distribution of DPS across Bengaluru's rural-urban interface.

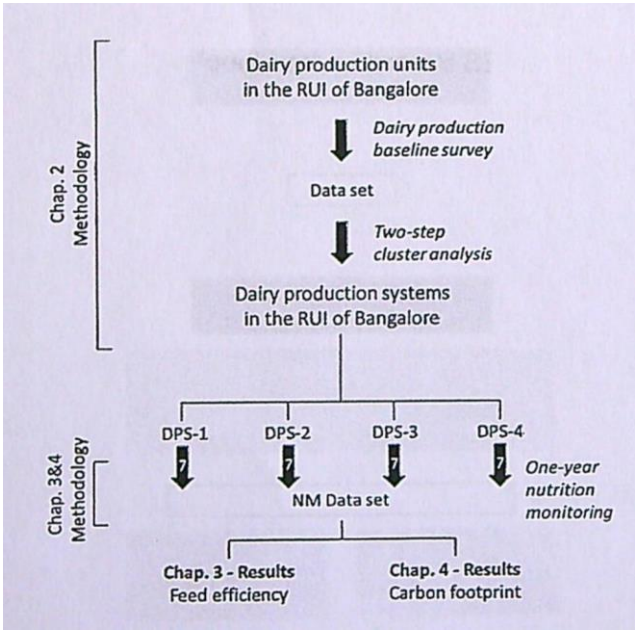


Figure 2 Graphical abstract of the present study, summarizing the different methodologies used and results obtained in each chapter. DPS = dairy production system; NM = nutrition monitoring.

Chapter 2: To identify and characterize the DPS co-existing in Bengaluru's rural-urban interface, a dairy production baseline survey was conducted with 337 dairy producers across six urbanization levels. Four DPS were identified through a two-step cluster analysis based on five predictors: the urbanization level of the settlement, reliance on self-cultivated forages, use of pasture, cattle in- and outflows within the herd and share of specialized dairy genotypes. DPS-1 was ubiquitous and extensive, with cattle feeding not relying on self-cultivated forages but rather on public grounds for pasture and forages collection, or market wastes, or both; DSP-2 was rural and semi-intensive, with cattle feeding relying on both pasture and self-cultivated forages, and a breeding management of specialized dairy genotypes. DPS-3 was the same as DPS-2 apart for their breeding management, which did not rely on specialized dairy genotypes. DPS-4 was rural and intensive with a feeding management relying on self-cultivated forages but not on pasture. Dairy producers in DPS-1 were typically landless producers and used mostly informal marketing channels to sell their milk, while those in DPS-2, DPS-3 and DPS-4 relied on dairy cooperatives for inputs and as milk marketing channel. Overall, Bengaluru's dairy sector had a well-established network of dairy cooperatives and was characterized by small-scale family farms with a homogenous socio-economic background and similar production practices. The SES revolving around rural dairy producers was typically dichotomized in rural production-oriented and urban consumption- oriented components with dairy cooperatives as intermediaries of the value chain and had milk as sole linkage between producers and consumers. Linkages based on the provision of fresh milk but also recycling and upgrading of Bengaluru's organic wastes, and socio-cultural services between urban dairy producers, consumers and the city in itself constituted a tight non- dichotomized SES (Figure

3). The Integration of dairy producers into the urban landscape was enhanced by the tightness of theses linkages, thus giving them access to better infrastructures (schools, hospitals) at the expense of the health and welfare of their cows.

Chapter 3: In order to quantify resource use efficiency, i.e. feed conversion efficiency, of Bengaluru's DPS, 28 dairy farms, 7 per DPS, were selected and monitored in 6-week intervals during one year: daily dry matter intake on-farm and at pasture, and energy and nutrient requirements (for maintenance, growth, pregnancy, locomotion, milk production) were collected for each cow. Daily dry matter intake (DMI) per kg of metabolic weight showed distinctly different feeding intensities that were linked to the reliance on self-cultivated forages or pasture or both. Coverage of the requirements of metabolizable energy and crude protein were variable in DPS1, while in DPS-2, DPS-3 and DPS-4, cows were mostly oversupplied. Milk offtake differed between DPS and, corrected to body weight, was affected by DPS, days-in-milk, DMI, genotype, coverage ratio for metabolizable energy, pregnancy and period of data collection. The extensive DPS-1 had the best feed conversion efficiency (1.00 kg DMI per kg energy-corrected-milk (ECM)), while feed conversion efficiency in DPS-2 (0.71 kg DMI $kg^{-1}$ ECM), DPS-3 (0.77 kg DMI $kg^{-1}$ ECM) and DPS-4 (0.72 kg DMI $kg^{-1}$ ECM) were crippled by the oversupply of cows. The decoupling of crop and livestock production in DPS-1 might however lead to environmental deterioration, especially in the case of urban dairy producers, with limited manure management options.

Chapter 4: In order to quantify the global environmental impact of Bengaluru's DPS, i.e. their emission intensity of greenhouse gasses expressed in terms of carbon dioxide equivalents ($CO_2$-req) derived from methane and nitrous oxide emissions due to enteric fermentation and manure management system, were computed from the previous dataset for six farms per DPS. The carbon footprint (CF) of milk differed according to the feeding intensity and strategy of each DPS: CF was highest in DPS-3 (1.95kg $CO_2$-eq $kg^{-1}$ ECM) and DPS-4 (1.52 kg $CO_2$-eq $kg^{-1}$ ECM). In opposition, CF was lowest in the extensive DPS-1 (0.91 kg $CO_2$-eq $kg^{-1}$ ECM) and intermediate in DPS-2 (1.21 kg $CO_2$-eq $kg^{-1}$ ECM). Cradle-to-farm-gate emission intensity of Bengaluru's dairy sector was estimated to be within the range of DPS with similar production levels in other countries.

Overall, the present study highlighted that: i) a range of DPS coexisted within Bengaluru's rural-urban interface, leading to different levels of production intensity, resource use efficiency and global environmental impact; ii) small-scale family farm can be efficient and emission conservative as they take advantage of local opportunities while dealing with the local constraints of an urbanizing environment; iii) urbanization impacts on dairy production are complex: urbanization leads to changes in labor availability but not directly in (decreasing) land availability for dairy production; it enhances market integration of rural and peri-urban dairy producers but does not lead to structural change in Bengaluru's dairy sector.

By improving the understanding of agricultural transitions in the case of dairy production in an urbanizing environment, the present study can support the implementation of future dairy development programs by pointing to local constraints and opportunities and the importance of several social-ecological components that should all be considered in such initiatives. It advocates that only recentering on the rote of farmers as crucial link between society and environment will allow developing sustainable food systems in our increasingly urban world and thus, durably tackle hunger worldwide. The SES framework casts new lights on on-going system transformation at sector level in an urbanizing environment as, from this perspective, the linkages and feedbacks between producers and consumers are of major importance, rather

than a single agricultural good or service. Ongoing urbanization processes in West Africa and Asia thus offer a unique opportunity to rethink the rote of small-scale farmers in the Global South and the future of our food systems: How to foster fair and good quality rural-urban linkages that maintain a green-loop equilibrium? Which place do (peri-)urban spaces occupy in the food supply strategy of emerging megacities? Because the agency of farmers is at the center of designing sustainable food systems, how can we empower them as the crucial link between society and environment? To conclude, the present study further paves the way for research on the impacts of urbanization on milk and livestock production systems in developing and transition countries with a broad system approach. Future research should especially focus on enhancing food systems' sustainability with the agency of small-scale farmers at its center to durably tackle hunger worldwide.

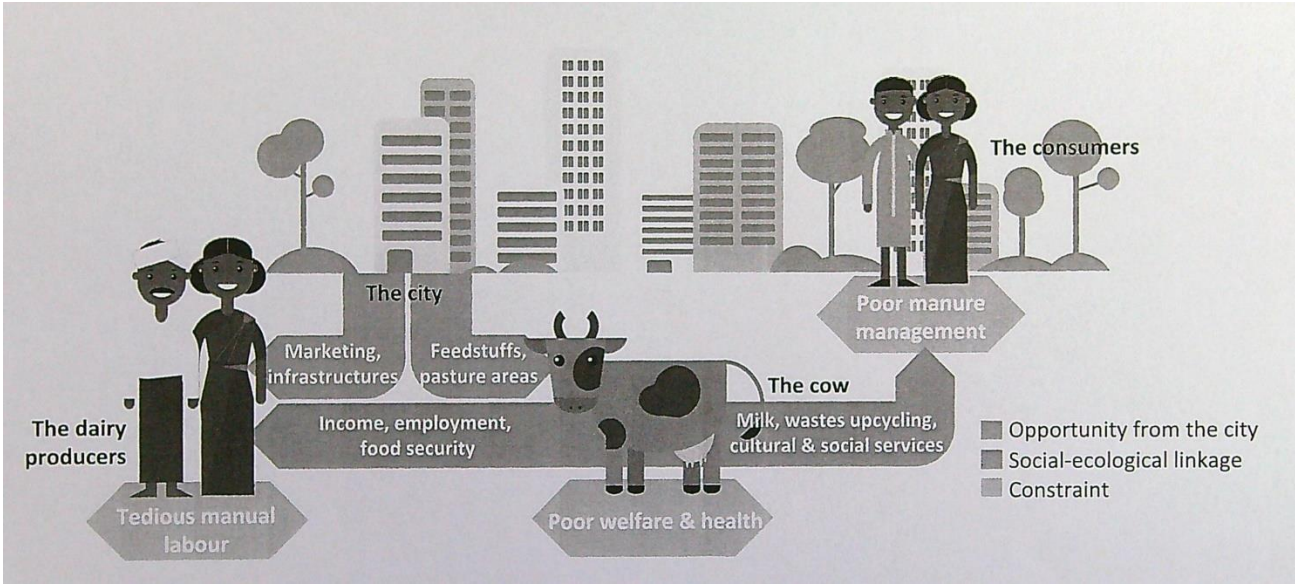


Figure 3 Illustration of the social-ecological system (SES) revolving around urban dairy producers, the social-ecological linkages between its different components, the opportunities offered by the city and the constraints for each of the SES component.

List of thesis publications

1. Alam M.S., Schlecht E., and Reichenbach M. (2022): Impacts of COVID-19 on Small-Scale Dairy Enterprises in an Indian Megacity Insights from Greater Bengaluru. Sustainability 14 (4), p. 2057. https://doi.org/10.3390/su14042057

2. Mullakkalparambil Velayudhan S., Brügemann K., Pinto A., Yin T., Reichenbach M., Sejian V., Bhatta R., Schlecht E., König S. (2022): Effects of Heat Stress across the Rural-Urban Interface on Phenotypic Trait Expressions of Dairy Cattle in a Tropical Savanna Region. Sustainability 14, p. 4590. https://doi.org/10.3390/su14084590

3. Pinto A., May K., Yin T., Reichenbach M., Malik P.K., Roessler R., Schlecht E., König S. (2021). Gastrointestinal nematode and Eimeria spp. infections in dairy cattle along a rural-urban gradient. Veterinary Parasitology: Regional Studies and Reports 25. https://doi.org/10.1016/j.vprsr.2021.100600

4. Pinto A., Yin T., Reichenbach M., Bhatta R., Malik P.K., Schlecht E., König S. (2020). Enteric Methane Emissions of Dairy Cattle Considering Breed Composition, Pasture Management, Housing Conditions and Feeding Characteristics along a Rural-Urban Gradient in a Rising Megacity. Agriculture 10 (628). https://doi.org/10.3390/agriculture 10120628

5. Pinto A., Yin T., Reichenbach M., Bhatta R., Schlecht E., König S. (2020): Phenotypic Dairy Cattle Trait Expressions in Dependency of Social-Ecological Characteristics along Rural-Urban Gradients. Sustainability 12 (21), p. 9021. https://doi.org/10.3390/su 12219021

6. Reichenbach M., Pinto A., König S., Bhatta R., Schlecht E. (2021 ): Dairy production in an urbanizing environment: typology and social ecological (dis-)connects in the megacity of Bengaluru, India. PLOS ONE 16(8): e0255791. https://doi.org/10.1371/journal.pone.0255791

7. Reichenbach M., Pinto A., Malik P. K., Bhatta R., König S., Schlecht E. (2021): Feed efficiency of dairy production in an urbanizing environment. A systems' approach in Bengaluru, India. Livestock Science, 104718. https://doi.org/10.1016/j.livsci.2021.104718