Quantifying beef production gaps of two farming systems in the Charolais basin, France

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1 Introduction

Sustainable intensification of livestock production systems is a way to realise the increasing global demand for meat. Current empirical studies reveal meat production levels obtained by best practices, but do not clarify the theoretically achievable (*i.e.* potential) and feed limited production. Potential production is defined by animal genotype and climate only (Fig. 1). Feed limited production is determined by genotype, climate, availability of drinking water, and the quality and quantity of feed. Actual production is the production that farmers achieve in practice. This production level is, next to genotype, climate, water, and feed, determined by diseases and stress in livestock (Van de Ven *et al.*, 2003).

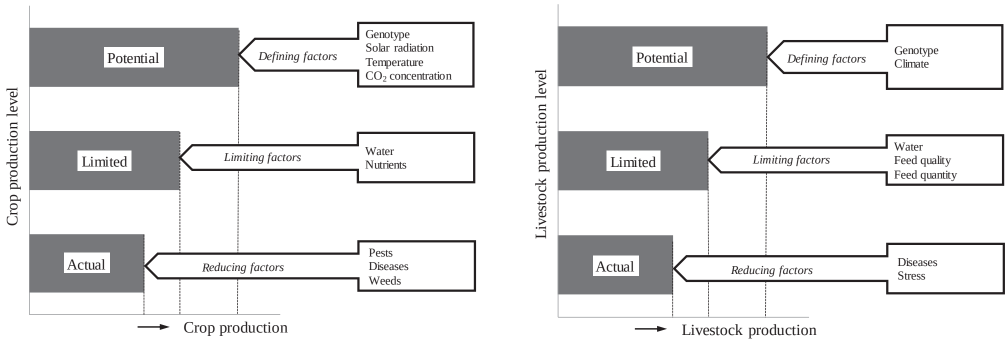

Fig. 1. Potential, limited, and actual production of crops (left) and livestock (right).

In crop production, the production ecological concepts of potential, limited, and actual production (Fig. 1) (Van Ittersum & Rabbinge, 1997) are generally used to give insight in the scope to increase production from their actual levels (Van Ittersum *et al.*, 2013). These concepts are also applicable to livestock production (Van de Ven *et al.*, 2003 ; Van der Linden *et al.*), but so far the effects of genotype, climate, feed quality, and feed quantity have not been quantified systematically using production ecological concepts in livestock production. This research, therefore, aims to quantify potential, feed quality limited, and actual beef production in two French beef production systems at herd level. Feed quantity limitation is not included.

2 Materials and Methods

A mechanistic, dynamic model was developed to simulate beef cattle growth based on genotype, climate, housing, feed quantity, and feed quality. This model is analogous to crop growth models that are based on the production ecological concepts. The beef cattle model combines feed digestion, thermoregulation, and feed utilisation sub-models in a novel way to simulate processes at animal level. Results from animal level are scaled up to herd level. Energy, heat, and protein flows are described in the model, which is programmed in R 3.0.2. Input data for the model are parameters for a specific genotype or breed, daily climate data, and information on housing, feed quality and feed quantity intake. The model was applied to two beef production systems with different feeding strategies of Charolais cattle in the Charolais Basin, France. System A corresponds to farm type 11111 and system B to farm type 31041 as described by Réseaux d'Elevage Charolais (2012). System A produced heavier animals and has a longer grazing period than system B. The fraction concentrates in the diet is larger in system B than in system A.
Potential production was expressed as a feed efficiency (FE, g beef kg^{-1} DM feed). Potential production in both systems was simulated with an *ad libitum* fed diet containing 65.8 % barley and 34.2% hay. This diet prevented feed quality and quantity limitation. Under potential production, FE was maximized at herd level, and all female calves were kept for replacement. Culling was set at 50% per year after birth of the first calf. Feed quality limited production was simulated with a diet containing concentrates and hay when cattle were housed during winter, and grass during other periods of the year. Concentrate intake (barley) was 4.8% of the DM intake in system A and 18.3% of the DM intake in system B,

which corresponded to the diet under actual production. Feed quality limited production was simulated with the same culling rates and slaughter weights as under potential production. Actual production was calculated from data provided by Réseaux d'Elevage Charolais (2012). Yield gaps were calculated as the difference between potential and actual production, and the difference between feed quality limited production and actual production. Relative yield gaps were calculated as the yield gap divided by potential or feed quality limited production.

3 Results and discussion

FE at herd level was highest under potential production and feed quality limited production, when male calves were slaughtered at 1000 kg. Potential production in systems A and B (Fig. 2) was slightly different (64.0 vs 64.4 g beef kg^{-1} DM feed). FE in system A was lower due to a longer grazing period and hence a higher energy requirement for grazing. Feed quality limited production, with the same culling rates and slaughter weights as under potential production, was lower in system A than in system B (51.7 vs 54.1 g beef kg^{-1} DM feed), which is explained by a lower fraction of concentrates in the diet. Actual production was lower in system A than in system B (24.9 vs 31.2 g beef kg^{-1} DM feed).

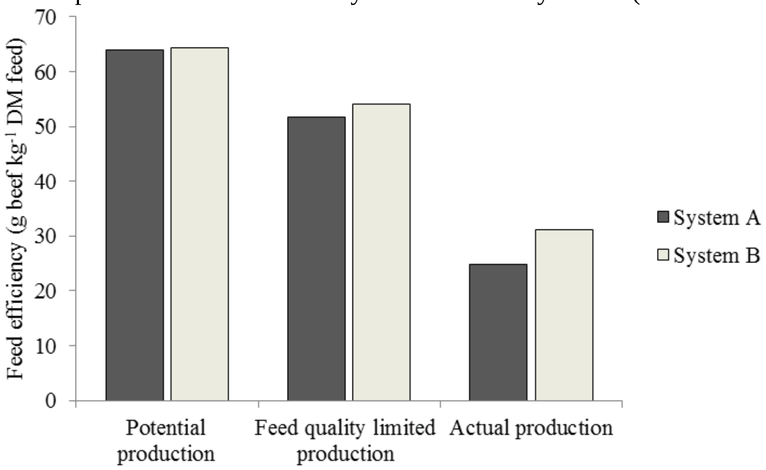

Fig. 2. Simulated feed efficiency in beef production systems A and B under potential, feed quality limited, and actual production.

The relative yield gap between actual and potential production was 61% in system A and 52% in system B, and the relative yield gap between actual and feed quality limited production was 52% in system A and 42% in system B. The latter yield gaps can be explained by feed quality limitation, as well as stress and diseases. In crop production, yields tend to plateau at 75-85% of potential or water limited production (*i.e.* minimum yield gaps equal 15-25%), and further yield gap mitigation is not economically or practically feasible (Van Ittersum *et al.*, 2013). In our study, simulated yield gaps are much larger than such minimum yield gaps. Grazing and suckler cow premiums might not urge farmers to mitigate current yield gaps, but also social factors (*e.g.* labour availability) may play a role. More model validation is required to further improve accuracy of the simulation results. Multiplying beef production (kg beef t^{-1} DM feed) and feed crop production (t DM ha^{-1} $year^{-1}$) results in the beef production per unit of land (kg beef ha^{-1} $year^{-1}$). Quantifying potential and limited production of crops *and* livestock according to production ecology allows us to assess land use per kg of animal product.

4 Conclusions

The production ecological concepts were successfully applied to livestock production. We benchmarked actual beef production relative to potential and feed quality limited production of two French beef production systems at herd level. Results indicate that potential production is more than two times the actual production in both systems. Hence, there is considerable scope to increase beef production in the Charolais basin, from a bio-physical perspective.

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