Mapping yield gaps in livestock production for sustainable intensification and food security

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The increasing demand for animal products and corresponding land use calls for sustainable intensification of the livestock sector. This PhD research is part of the project 'Mapping for sustainable intensification' executed at Wageningen University, the Netherlands. The PhD research aims to develop livestock growth models to estimate the scope for intensification, to identify constraining factors in livestock production, and to explore management options. Model results can be used in policy to target specific areas with tailored management options to increase the effectiveness of investments in the livestock sector.

Food demand, agriculture, and intensification

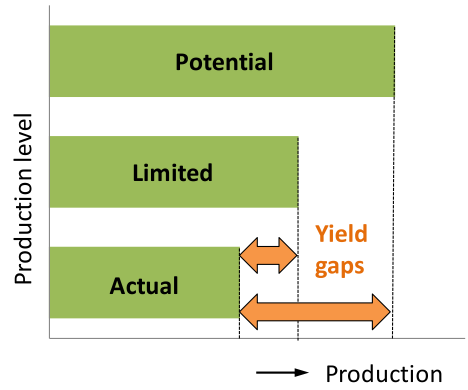
The global demand for food will increase 70% between 2005 and 2050, according to projections of the FAO (Food and Agriculture Organisation)[1]. Future diets are expected to contain more animal protein, which increases the demand for feed crops.

The livestock sector requires 70% of the agricultural land[2], and 39% of the arable land is used for production of livestock feed[3]. Feed production may compete with the production of human food crops, which may be increasingly the case in future. Yet, livestock production supplies one-third of the protein in the human diet[3], and contains high levels of essential minerals, such as iron and zinc.

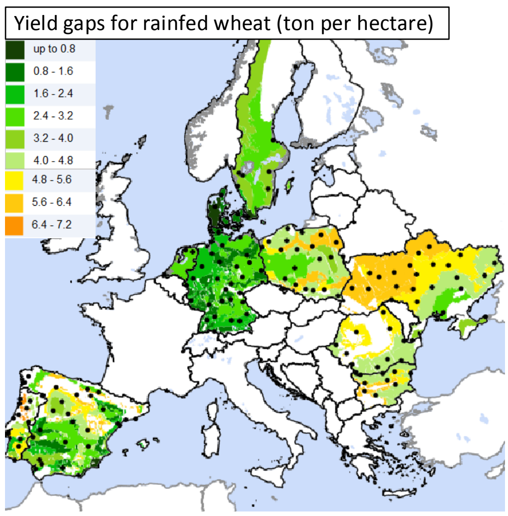
Increasing livestock production per hectare sustainably is generally considered an important strategy to contribute to improve global food security[4]. Sustainable intensification reduces the expansion of agricultural land at the expense of nature and biodiversity. Assessing the scope for sustainable intensification in livestock production can be based on the same principles being used to assess the scope for sustainable intensification in crop production[5,6].

Sustainable intensification in crop production

The amount of crops that can be produced per hectare, in addition to the actual production, is named the yield gap. Crop growth models are widely used to estimate yield gaps, which are calculated from the simulated potential or water-limited crop production and the actual crop production[7].

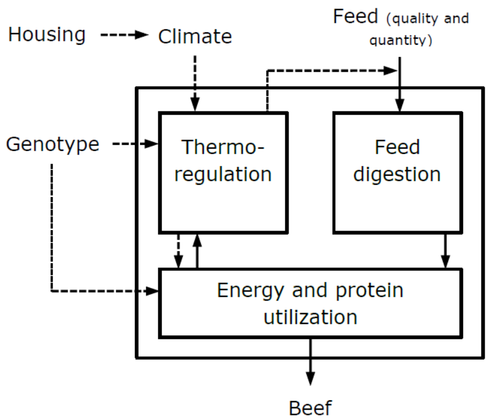


Yield gaps for crop production have been quantified for a variety of crops in many different countries. The figure below is from the Global Yield Gap Atlas and illustrates the yield gaps for wheat in Europe[8].



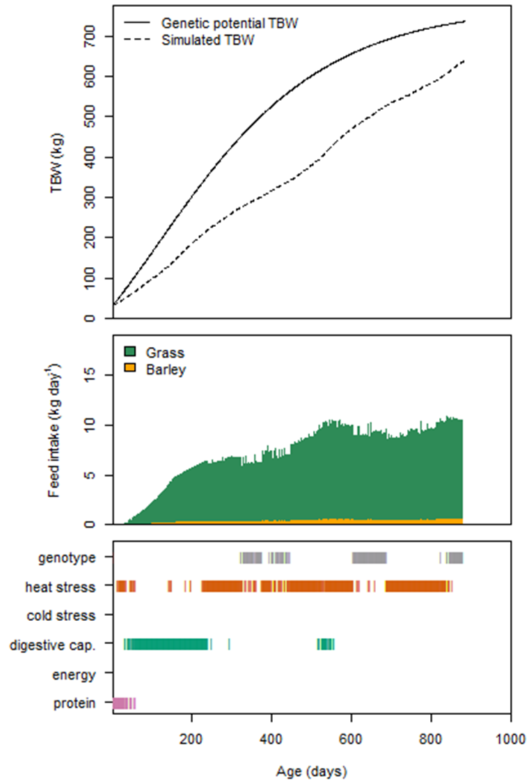
Sustainable intensification in livestock production

The methods used to assess the scope for intensification in crop production can be applied to livestock production too[5,6]. A generic model has been developed recently to simulate potential and feed-limited growth of beef cattle. This model is named LiGAPS-Beef (Livestock simulator for Generic analysis of Animal Production Systems). LiGAPS-Beef deals with thermoregulation, feed intake, feed digestion, and energy and protein utilization for physiological processes in animals, such as growth[9].



The model lists the constraining biological factors for growth of beef cattle. Potential production is determined by the genotype or breed and the climate. Feed quality and quantity are factors limiting production. Usually, the constraining factors for growth vary during the lifetime of animals[9]. As an illustration, the composed figure on the top-right of this page indicates the simulated total body weight (TBW), feed intake, and the constraining factors for growth for ¾ Shorthorn × ¼ Brahman cattle in Australia. A small fraction of the diet consists of barley. The simulated TBW was below the genetic potential TBW, mainly due to the constraining factors heat stress (related to the climate) and the digestive capacity of the animals (related to feed quality).

Estimations for weight gain from LiGAPS-Beef have been compared to measured weight gain from experiments performed in different countries with different breeds. This exercise showed that the estimations for weight gain from LiGAPS-Beef corresponded reasonably well to the measured



weight gain, which underpins the usefulness of the model[10].

Beef production, feed intake, and feed efficiency are obtained for individual animals. These data are scaled up from animal level to herd level, which accounts for the differences in feed intake and beef production of cows and calves in beef production systems[5].

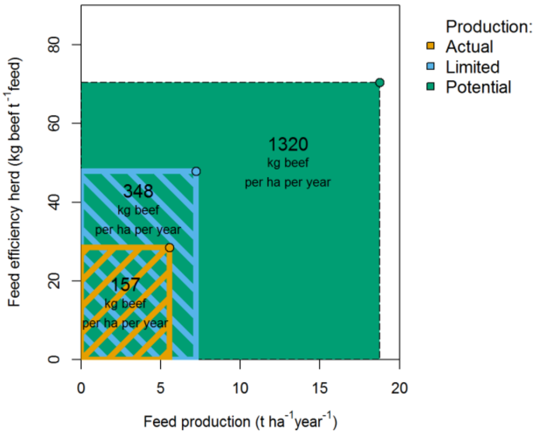
Next, feed efficiency of livestock and feed crop production together can be used to estimate the potential and limited livestock production per hectare[6].

$$\text{Livestock production (kg ha}^{-1}\text{ year}^{-1}) =$$

$$\text{feed efficiency (kg product ton}^{-1}\text{ feed)} \times \text{feed crop production (ton feed ha}^{-1}\text{ year}^{-1})$$

Grass sward and cattle strongly interact in grazing systems. The model LiGAPS-Beef and a grass growth model have been integrated to simulate beef production on pastures. The integration allows optimization of stocking densities to maximize the beef production per hectare. Accounting for feed crop and livestock production shows that high quality feeds result in the highest feed efficiencies, but not necessarily in the highest livestock production per hectare.

Comparing the potential or limited livestock production with the actual livestock production per hectare allows to calculate the yield gap for livestock production. For example, the yield gap between limited (348 kg beef) and actual beef production (157 kg beef) was 191 kg beef per hectare per year in a farm with Charolais cattle in France, as indicated in the figure below. Under potential production of crops and cattle, yield was more than eight times as large as the actual production.



From yield gaps to improvements

After estimating yield gaps for livestock, several steps are to be taken to move from yield gaps to improvements in agriculture:

- Identify the most constraining biological factors for livestock growth
- Make an inventory of management options that mitigate the most constraining factors
- Eliminate the options that are not feasible for farmers due to economic, social, cultural, or ethical considerations (*e.g.* animal welfare). For instance, in a case study for farms with Charolais cattle in France we found that many management options for yield gap mitigation are not economically attractive.
- Explore the effects of feasible options on livestock production with model simulations and experiments
- Select the most promising and effective management options for yield gap mitigation.

These steps have been used in crop science, and their application has contributed to mitigation of yield gaps in several cases[11]. The livestock sector may benefit, therefore, from the application of these steps too.

Upscaling from farm to globe

Crop and livestock models are used to estimate yield gaps for specific farms in a specific location. For models like LiGAPS-Beef, input data on breeds and feed availability are available in various FAO databases for the major areas in the world where livestock is kept. Upscaling from the farm level to country or global level allows to compare yield gaps among different regions. In addition, the effectiveness of feasible management options can be simulated and explored for different regions.

Implications for policy

Estimating yield gaps in the livestock sector for extensive areas would allow to identify the areas that are hotspots for yield gap mitigation, and how yield gaps can be mitigated[12]. This knowledge can be input for policy makers to:

- Target specific areas with management options tailored to the local conditions[12]
- Increase the effectiveness of investments in the livestock sector
- Estimate the contribution of yield gap mitigation to the sustainable development goals, for example to reduce hunger and poverty.

More information

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Animal Production Systems group
www.wageningenur.nl/aps

Plant Production Systems group
www.wageningenur.nl/pps

Global Yield Gap Atlas
www.yieldgap.org

Research project 'Mapping for Sustainable Intensification'

http://www.wageningenur.nl/en/About-Wageningen-UR/Strategic-Plan/Strategic-plan-2011-2014/Mapping-for-Sustainable-Intensification.htm

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