Feed Use in Scenarios

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Eric Kemp-Benedict

Introduction

A methodology is presented for estimating changes in the productivity of meat production, given by the ratio of feed energy requirements to meat production. The methodology, which can be applied when data are scarce, makes use of data that are generally available in national statistical yearbooks or FAO statistics. The methodology is then applied in a scenario, implemented using the IPAT-S scenario scripting language. The results of running the scenario are discussed in this case study. The full script is included as an appendix, and it can also be downloaded from the IPAT-S web site. Readers who are interested in exploring and modifying the scenarios can download the script and the free IPAT-S software from http://www.kb-creative.net/IPAT_S.

In the general IPAT framework, production or consumption lead to environmental pressures, modified by changes in technology. For agricultural systems, changes in "technology" are reflected in changes in productivity. Such changes can be caused either by changing practices within a given system (for example, by practicing conservation tillage on rainfed fields) or by changing from one system to another (for example, by irrigating fields). In the case of livestock feed use, one component of the technology factor, considered in this document, is the amount of feed required to produce a given amount of meat. Other factors, not considered here, have to do with the feed source, such as the productivity of grazing land or the properties of the feed mix; changing production systems; or shifting production from one kind of livestock to another. The ratio of feed requirements to meat production is highly relevant to sustainability scenario studies, because it can be used to link agricultural production to a resource impact.

Unfortunately, agricultural reports and statistics rarely report the needed figures. Instead, livestock productivity is given indirectly in terms of animal weight (either as liveweight or carcass weight), the offtake rate and sometimes the dressing fraction. The *liveweight* is the weight of the animal before slaughter, while the *carcass weight* is the weight after the animal has been slaughtered and the offals removed. The *dressing fraction*, which is the ratio of the two weights, shows little change for a given type of livestock, and can generally be assumed to be constant in a scenario. The *offtake rate* is the ratio of the number of animals slaughtered over some time (generally a year) to the total size of the herd at some point in time (the number of head of livestock).

For the common situation where detailed statistics are not available, this document describes an approach to estimating changes in feed requirements in scenarios using the liveweight (or carcass weight) and the offtake rate. The result is given below as Equation (8). It is very rough, but can be used for medium-to-long-term scenarios, where the uncertainties from other sources are large enough that such a rough calculation can be useful. It should give a reasonable order-of-magnitude estimate, in the absence of more reliable estimates.[1]

[1] This approach is also described in Kemp-Benedict et al. (2002) More detailed approaches can be found in the IPCC *Guidelines for Greenhouse Gas Inventories* (IPCC/OECD/IEA, 1996) and the FAO's *Livestock Development Planning System* (Lalonde and Sukigara, 1997)

The Methodology

Feed requirements are given by the total number of animals multiplied by feed requirements per head:

$$E_F = H \times I_F \quad , \tag{1}$$

where E_F is feed energy, H is the number of head of animals and I_F is the *feed intensity*, the feed requirements per head.

The total meat produced is given by the number of head, multiplied by the offtake rate and the carcass weight:

$$M = H \times R \times W_c \ , \tag{2}$$

where M is meat production, R is the offtake rate and W_c is the carcass weight.

The meat-production system can be thought of as more productive if, for a given amount of feed energy, more meat is produced.[2] Accordingly, the productivity parameter, π, is set as the total feed energy required to produce a certain amount of meat. That is,

$$\pi \equiv \frac{M}{E_F} = \frac{R \times W_c}{I_F} \ . \tag{3}$$

This can be put in terms of an index relative to some reference year, such as the base year in a scenario:

$$\pi = \pi_0 \times \left(\frac{R}{R_0}\right) \times \left(\frac{W_c}{W_{c,0}}\right) \times \left(\frac{I_{F,0}}{I_F}\right) , \tag{4}$$

where a subscript "0" indicates an initial (or base year) value. However, because the ratio of the carcass weight to the liveweight does not change much over time, this can be rewritten:

$$\pi = \pi_0 \times \left(\frac{R}{R_0}\right) \times \left(\frac{W_l}{W_{l,0}}\right) \times \left(\frac{I_{F,0}}{I_F}\right) , \tag{5}$$

where W_l is the liveweight. Next, the feed energy index per head can be related to the liveweight, using the relation:

$$\frac{I_F}{I_{F,0}} = \left(\frac{W_l}{W_{l,0}}\right)^{0.75} \ . \tag{6}$$

[2]This is a commonly used, but problematic, definition. In many countries, livestock production systems offer much more beyond milk, meat and fiber. For example, they can be an investment and may be used to signal societal position.

This relationship is used frequently when estimating energy requirements for livestock, as well as for other animals. See, for example, the chapter "Energy" in the U.S. National Research Council's Nutrient Requirements of Beef Cattle, 7th Edition (NRC, 1996).[3]

Equation (6) allows the productivity index to be written

$$\pi = \pi_0 \times \left(\frac{R}{R_0}\right) \times \left(\frac{W_l}{W_{l,0}}\right) \times \left(\frac{W_{l,0}}{W_l}\right)^{0.75}, \quad (7)$$

which can then be simplified to

$$\pi = \pi_0 \times \left(\frac{R}{R_0}\right) \times \left(\frac{W_l}{W_{l,0}}\right)^{0.25}. \quad (8)$$

The indices on the right-hand side of Equation (8) can generally be estimated from historical data, so approximate historical productivity indices can be constructed. Alternatively, figures for the offtake rate and liveweight indices could be assumed in a scenario, and the productivity index constructed from them, to create scenarios of feed energy intake corresponding to a certain level of meat production in the scenario. This is the approach taken in the next section.

The Scenario

To make the methodology more concrete, an explicit scenario is presented here. The entire scenario is given as an IPAT-S script in the appendix to this case study. Both the script and the free IPAT-S software is available for download from http://www.kb-creative.net/IPAT_S. Readers interested in adapting or modifying the scenario may wish to download the software for their own use.

Most of the scenario script is devoted to entering the base-year data on livestock production and feed use. A smaller portion implements the calculations outlined above (for meat) and, for milk, a simple productivity index. In the scenario, which is applied to a fictional country, most meat production is rising fairly rapidly, except for sheep and goats, for which production is stabilizing. However, productivity gains, expressed in terms of liveweights and offtake rates, offset much of the increased production, limiting increases in demand for feed concentrates and grazing land. For the detailed assumptions, please see the appendix.

The scenario is summarized here, using figures exported from the IPAT Studio program (the GUI interface to the IPAT-S language interpreter). As shown in Figure 1, production rises for all livestock between 2000 and 2010, but between 2010 and 2020, production of sheep and goats begins to decline.

[3]Note that when estimating energy requirements, Equation (6) is usually applied to a single animal or a group of very similar animals. Here it is applied to an average over a range of different kinds of animals. The result is different from what it would be if the energy requirements were first calculated for each type of livestock and then averaged (this is the proper way to calculate average energy requirements). However, FAO statistics do not allow for the more appropriate alternative. If the range of animal liveweights is not very large then the procedure described here should be sufficient for a long-range scenario exercise.

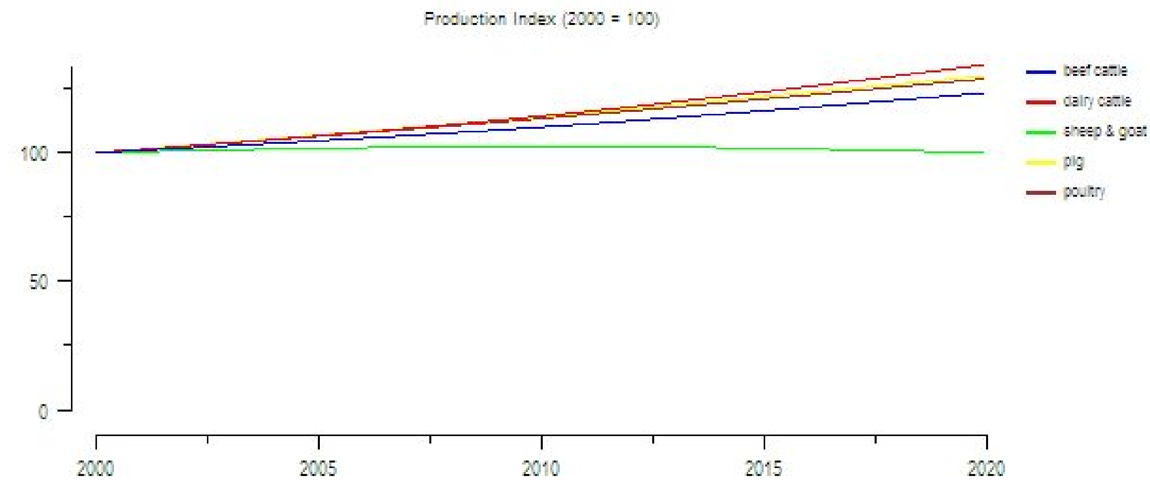

Figure 1: Livestock production in the scenario

Despite the rise in livestock production, productivity increases lead to only modest increases in feed requirements, as shown in Figure 2.

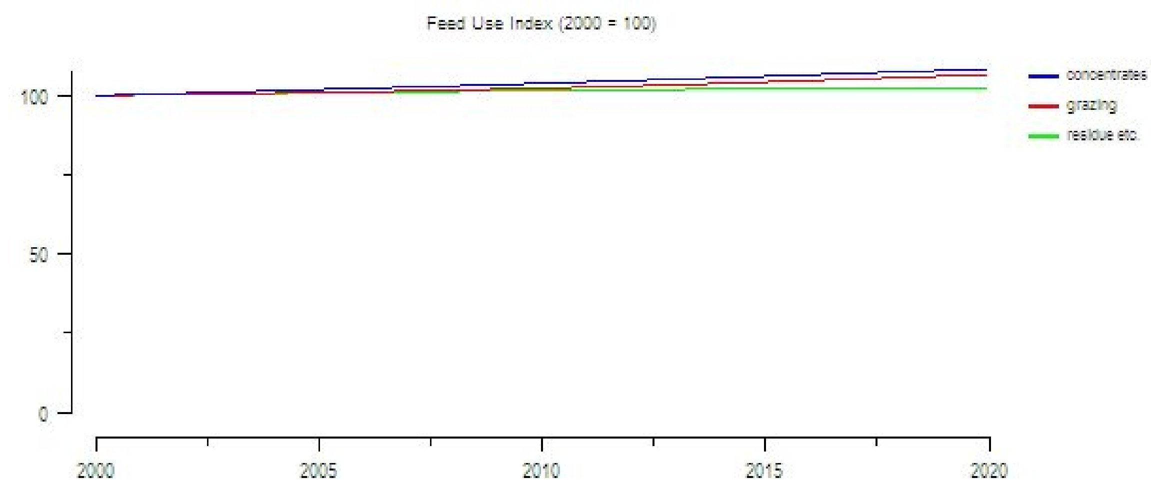

Figure 2: Feed use in the scenario, by feed

Moreover, although requirements for grazing feed *energy* increases, improvements in grazing land productivity limit the increase in requirements for grazing land itself, as shown in Figure 3. In fact, requirements for grazing land decline slightly in the first decade of the scenario before rising again as productivity growth slows.

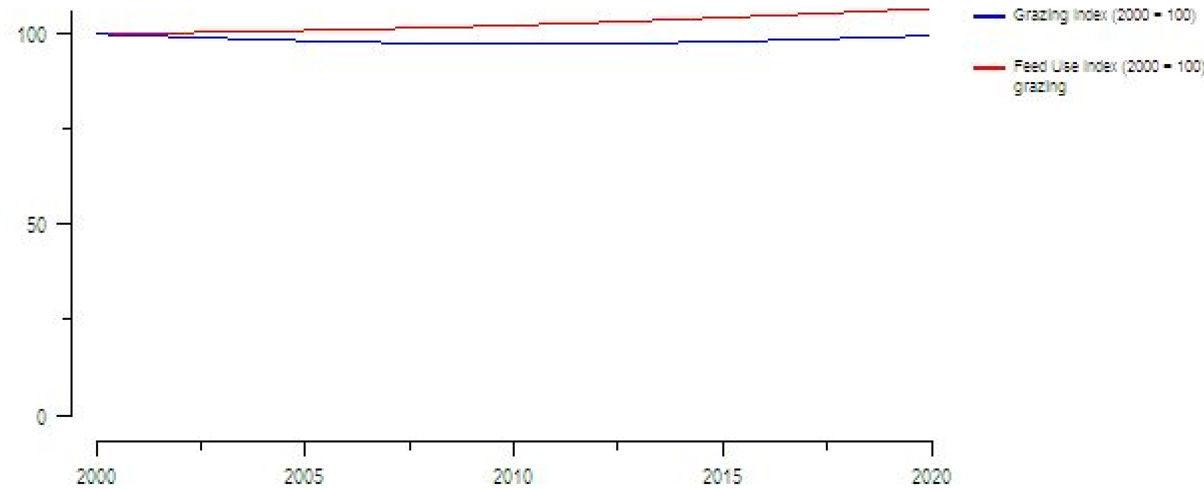

Figure 3: Grazing feed energy requirements and requirements for grazing land

Varying changes in productivity for different kinds of livestock and a changing mix of livestock leads to (moderate) changes in the feed requirements by different kinds of livestock over the scenario, as shown in Figure 4. The most significant change is the sharp drop in requirements for sheep and goats, due to a combination of declining production and increasing productivity.

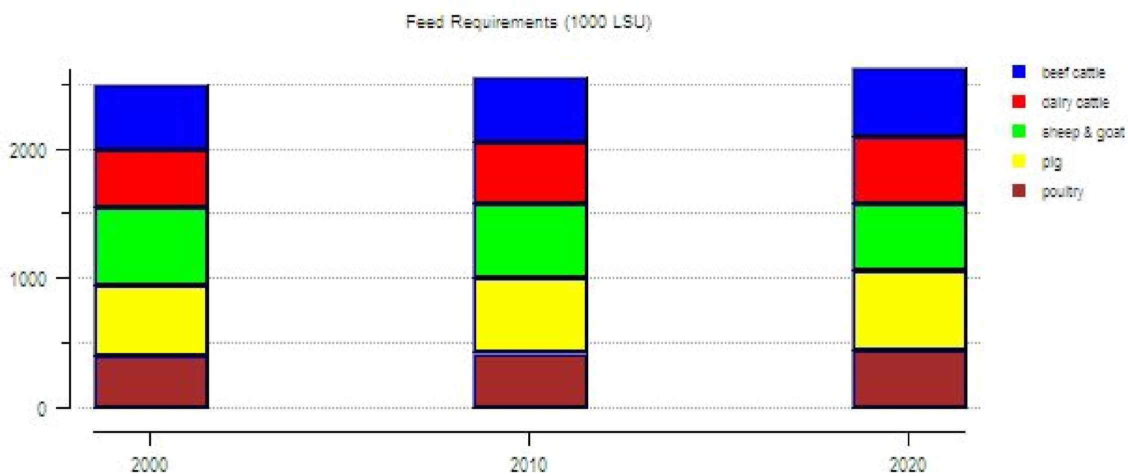

Figure 4: Feed requirements by type of livestock

Conclusion

This case study is essentially a methodology note. The scenario itself is not of great interest. However, if the methodology presented here were used as part of a larger scenario on the resource impacts of agricultural change, it could be of great interest. It is hoped that the approach presented in this case study can be of use to scenario analysts interested in agricultural production.

References

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Lalonde, L.-G. and T. Sukigara. 1997. *$LDPS^2$ User's Guide*. Rome: Food and Agriculture Organization, Animal Production and Health Division. Report and model available from: http://www.fao.org/WAICENT/FAOINFO/AGRICULT/aga/LSPA/Ldps2/Default.htm.

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Appendix: IPAT-S Script

```
# IPAT-S script implementing a feed demand scenario, driven by livestock
# production

base year 2000
scen years 2010 2020

dim livestock 'beef cattle' 'dairy cattle' 'sheep & goat' \
      'pig' 'poultry'
dim feed 'concentrates' 'grazing' 'residue etc.'

#######################################
##
## Variables
##
#######################################
comment:
      FeedTable:   Detailed feed allocation by type of livestock and
                   type of feed.
      FeedEnerReq: Sum FeedTable over "feed"
      FeedSupply:  Sum FeedTable over "livestock"
      Production:  Domestic livestock production by type of livestock
      GrazArea:    Total grazing area
:comment
summvar FeedTable{livestock feed} # Feed supply in 1000 LSU
summvar FeedEnerReq{livestock} # Feed energy requirements in 1000 LSU
summvar FeedSupply{feed} # Feed supply by feed in 1000 LSU

summvar Production{livestock} # Production in kt

summvar GrazArea   # Grazing area in Mha

comment:
Productivity indices
* Meat-producing
      liveweight:  Liveweight index
      offtake:     Offtake index
* Dairy-producing
      dairyProd:   Dairy productivity index (kt milk/LSU)
* Land use
      grazProduct: Index of productivity of grazing land (LSU/ha)
:comment
ratio liveweight{livestock}, offtake{livestock}
ratio dairyProd
ratio grazProduct

########################################
##
## Base-year feed allocation
##
########################################
# Beef cattle
ditto livestock = 'beef cattle':
FeedTable.0{'' feed = 'concentrates'} = 10% * 500
FeedTable.0{'' feed = 'grazing'} =  70% * 500
FeedTable.0{'' feed = 'residue etc.'} = (100% - 10% - 70%) * 500

# Dairy cattle
ditto livestock = 'dairy cattle':
FeedTable.0{'' feed = 'concentrates'} = 70% * 450
```

```
FeedTable.0{'' feed = 'residue etc.'} = (100% - 70%) * 450

# Sheep & goats
ditto livestock = 'sheep & goat':
FeedTable.0{'' feed = 'concentrates'} = 30% * 600
FeedTable.0{'' feed = 'residue etc.'} = (100% - 30%) * 600

# Pigs
ditto livestock = 'pig':
FeedTable.0{'' feed = 'concentrates'} = 70% * 550
FeedTable.0{'' feed = 'residue etc.'} = (100% - 70%) * 550

# Poultry
ditto livestock = 'poultry':
FeedTable.0{'' feed = 'concentrates'} = 20% * 400
FeedTable.0{'' feed = 'residue etc.'} = (100% - 20%) * 400

# Sum across sources to give total feed for animals
summarize FeedTable as FeedEnerReq

#########################################
##
## Livestock production in BY & scenario
##
#########################################
ditto livestock:
Production{'' = 'beef cattle'} = 300, <330, 370>
Production{'' = 'dairy cattle'} = 3500, <4000, 4700>  # Milk & products
Production{'' = 'sheep & goat'} = 400, <410, 400>
Production{'' = 'pig'} = 500, <570, 650>
Production{'' = 'poultry'} = 450, <510, 580>


liveweight = incr[< 10% >]  # Increase 10% between each successive
scenario year
offtake = incr[< 5% >] # Increase 5% between each successive scenario
year
dairyProd = gr(<0.75%>) # Gradual increase in dairy productivity

GrazArea.0 = 127
grazProduct = index[<1.05, 1.02>]  # Change in grazing land productivity

#########################################
##
## Feed requirements in the scenario
##
#########################################
# Production drives feed energy requirements, but moderated by
#   - offtake rate (higher rate reduces feed req)
#   - liveweight (more energy per animal, to 0.75 power, but more meat
per animal)

:: Production >> liveweight^0.75/(offtake * liveweight) -> FeedEnerReq

# Calculate for dairy, which doesn't use above formula
# Note: Have to do this one second
ditto livestock = 'dairy cattle':
:: Production {''} >> 1/dairyProd -> FeedEnerReq {''}

# Calculate feed requirements by feed source, and sum across livestock
#   to give total requirements by type of feed
# Assume scenario feed mixes for each livestock type are
```

```
#   the same as in the base year
summarize FeedEnerReq >>-> FeedTable as FeedSupply

# Calculate grazing area
::  FeedSupply{feed = 'grazing'} >> 1/grazProduct -> GrazArea

##########################################
##
## Report results
##
##########################################
report 100 * Production/Production.2000 as \
      "Production Index (2000 = 100)"
report FeedEnerReq as "Feed Requirements (1000 LSU)"
report 100 * GrazArea/GrazArea.2000 as "Grazing Index (2000 = 100)"
report 100 * FeedSupply/FeedSupply.2000 as "Feed Use Index (2000 = 100)"
```