On the Economics of Genetic Improvement Programmes

Leo Dempfle

Department of Animal Science

University of Technology Munich/Germany

Is it economic to establish genetic improvement programmes in developing countries **??**

Many programmes in Europe and Amerika!

Very rare in developing countries!

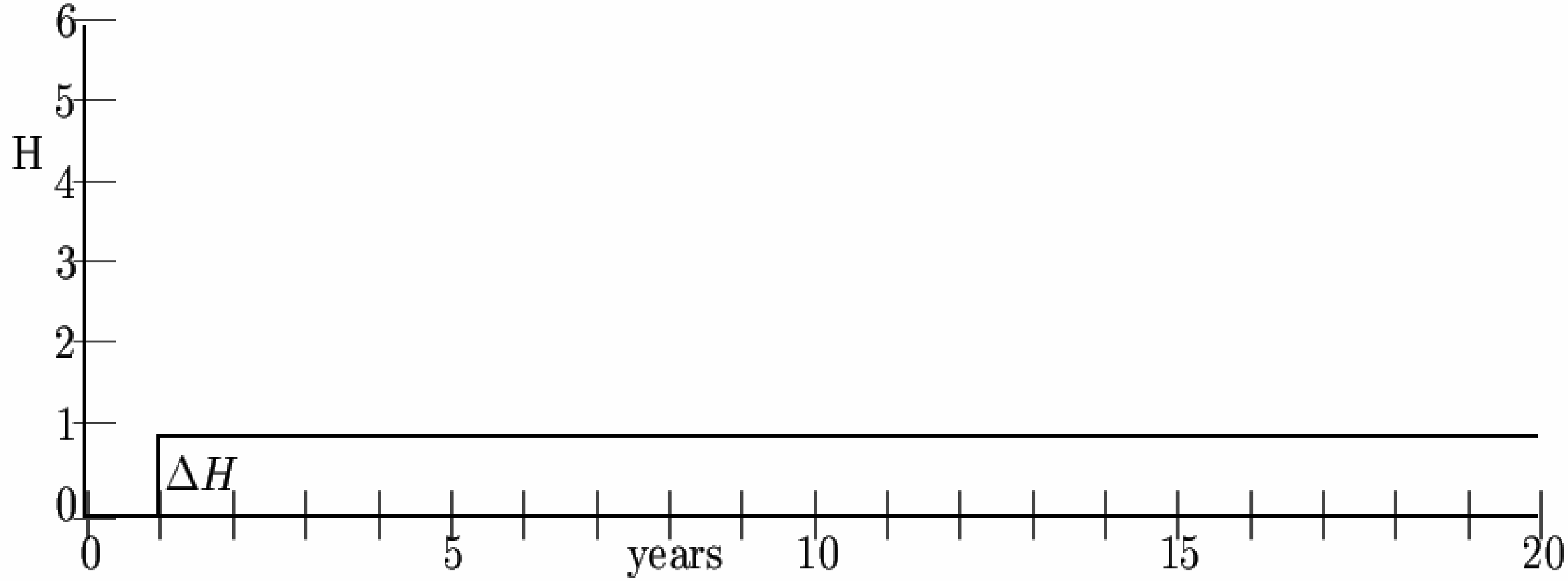
Genetic improvement is slow with only small increments (eg 1% of the mean)

However, breeding has some remarkable properties, like being

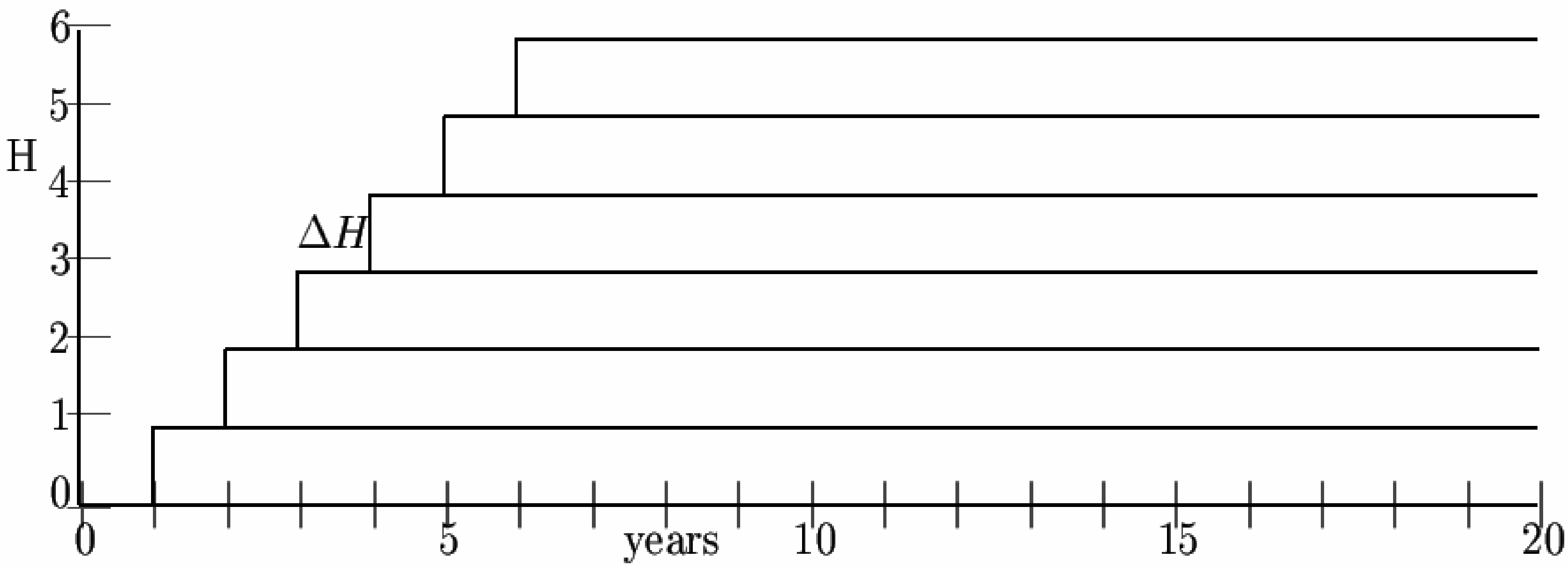
- permanent
- cumulative
- multiplicative

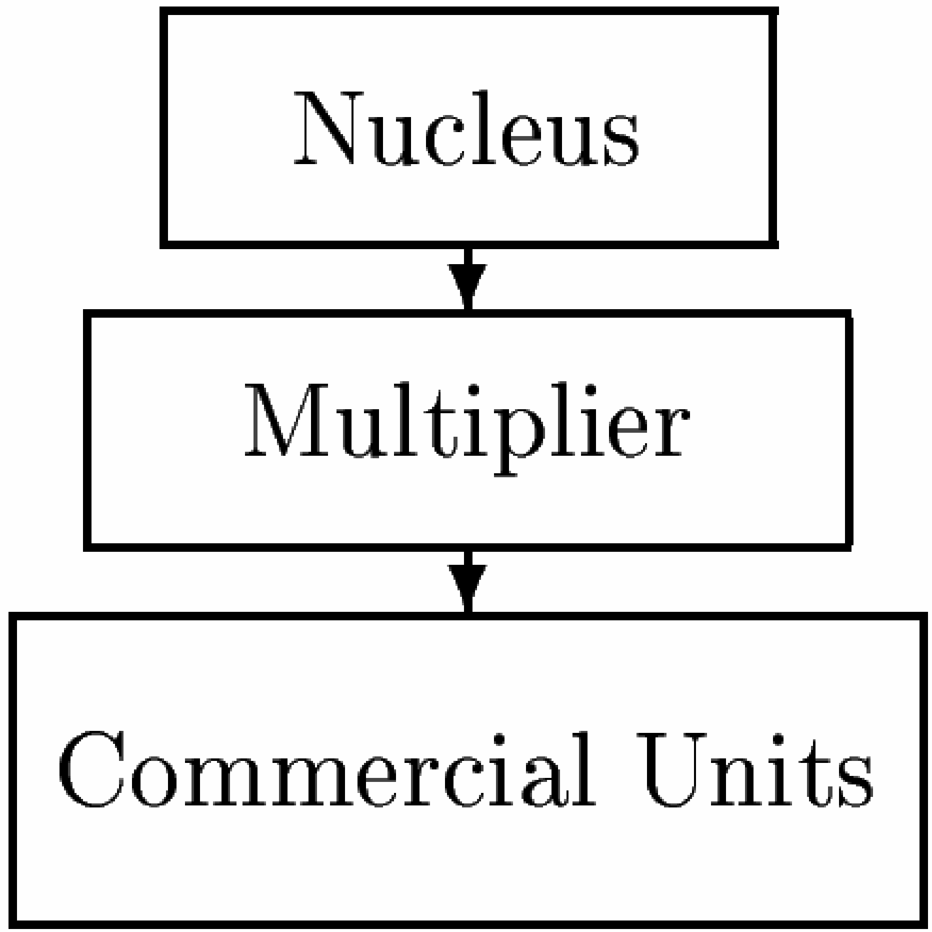
which is favorable for the economics of it.

- In the next three slides the
  - Genetic level is indicated following one cycle of selection (permanence of genetic improvement)
  - Genetic level after several cycles of selection (cumulative property)
  - The typical pyramid structure of modern breeding schemes (multiplicative property)

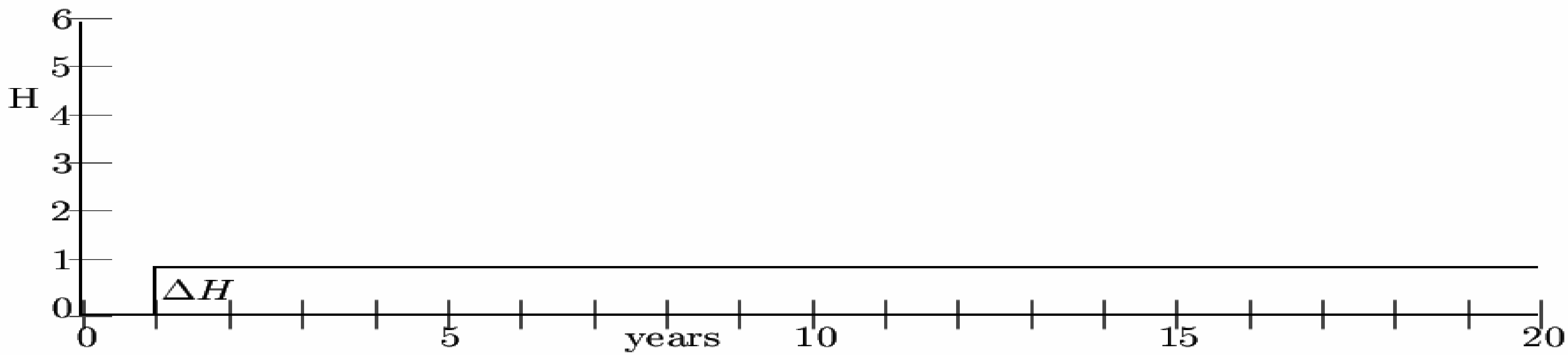


H
6
5
4
3
2
1
0
ΔH
0
5
years
10
15
20


H
6
5
4
3
2
1
0
ΔH
0
5
years
10
15
20


Nucleus
Multiplier
Commercial Units

- In the next slides the economic consequences are indicated
  - Discounting cost and returns
  - Impact of interest rate and time horizon



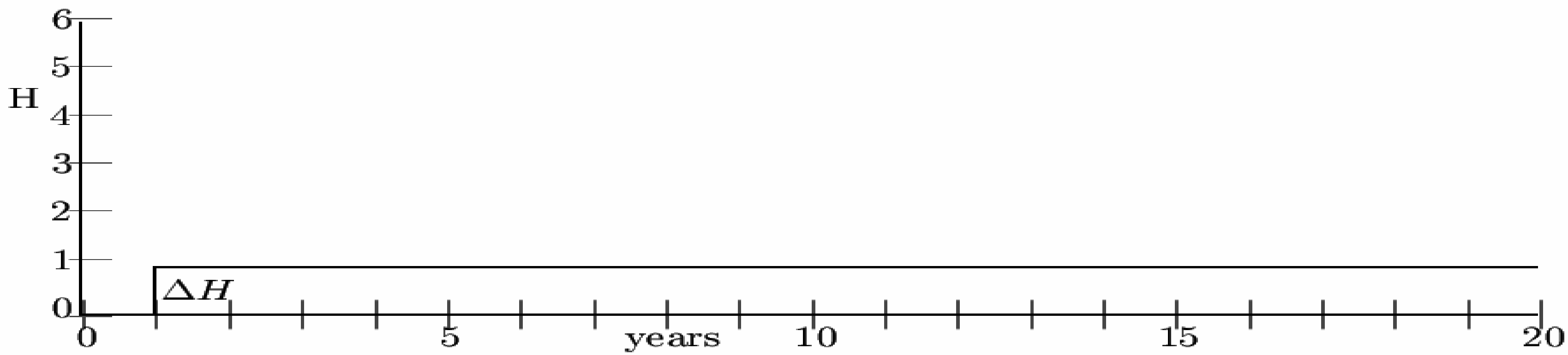
$$NPV(0) = -c_o + \frac{\Delta H \cdot N}{(1+i)^2} + \frac{\Delta H \cdot N}{(1+i)^3} + \frac{\Delta H \cdot N}{(1+i)^4} + \cdots + \frac{\Delta H \cdot N}{(1+i)^k} + \cdots$$

$$NPV(0) = -c_o + \frac{\Delta H \cdot N}{(1+i)^2}[1 + (\frac{1}{1+i})^1 + (\frac{1}{1+i})^2 + (\frac{1}{1+i})^3 + \cdots + (\frac{1}{1+i})^{T-2}]$$

$$= -c_o + \Delta H \cdot N \frac{1}{i(1+i)}[1 - (\frac{1}{1+i})^{T-1}]$$

The value of $\frac{1}{i(1+i)}[1-(\frac{1}{1+i})^{T-1}]$ is

T:	10	15	20	30	50	∞
$i = 0.03$:	7.56	10.97	13.91	18.63	24.76	32.36
$i = 0.04$:	7.15	10.16	12.63	16.33	20.52	24.04
$i = 0.05$:	6.77	9.43	11.51	14.42	17.30	19.05



$$NPV(0) = -c_o + \frac{\Delta H \cdot N}{(1+i)^2} + \frac{\Delta H \cdot N}{(1+i)^3} + \frac{\Delta H \cdot N}{(1+i)^4} + \cdots + \frac{\Delta H \cdot N}{(1+i)^k} + \cdots$$

$$NPV(0) = -c_o + \frac{\Delta H \cdot N}{(1+i)^2}[1 + (\frac{1}{1+i})^1 + (\frac{1}{1+i})^2 + (\frac{1}{1+i})^3 + \cdots + (\frac{1}{1+i})^{T-2}]$$

$$= -c_o + \Delta H \cdot N \frac{1}{i(1+i)}[1 - (\frac{1}{1+i})^{T-1}]$$

- A case study

  N‘Dama Breed in West Africa

  About 5 Mill animals

  Used for milk, meat and traction

  Breeding goal:

  Improvement of milk and meat without loss of disease resistence and other adaptive traits

  AI is not regarded as feasible!

- In the next slides you see

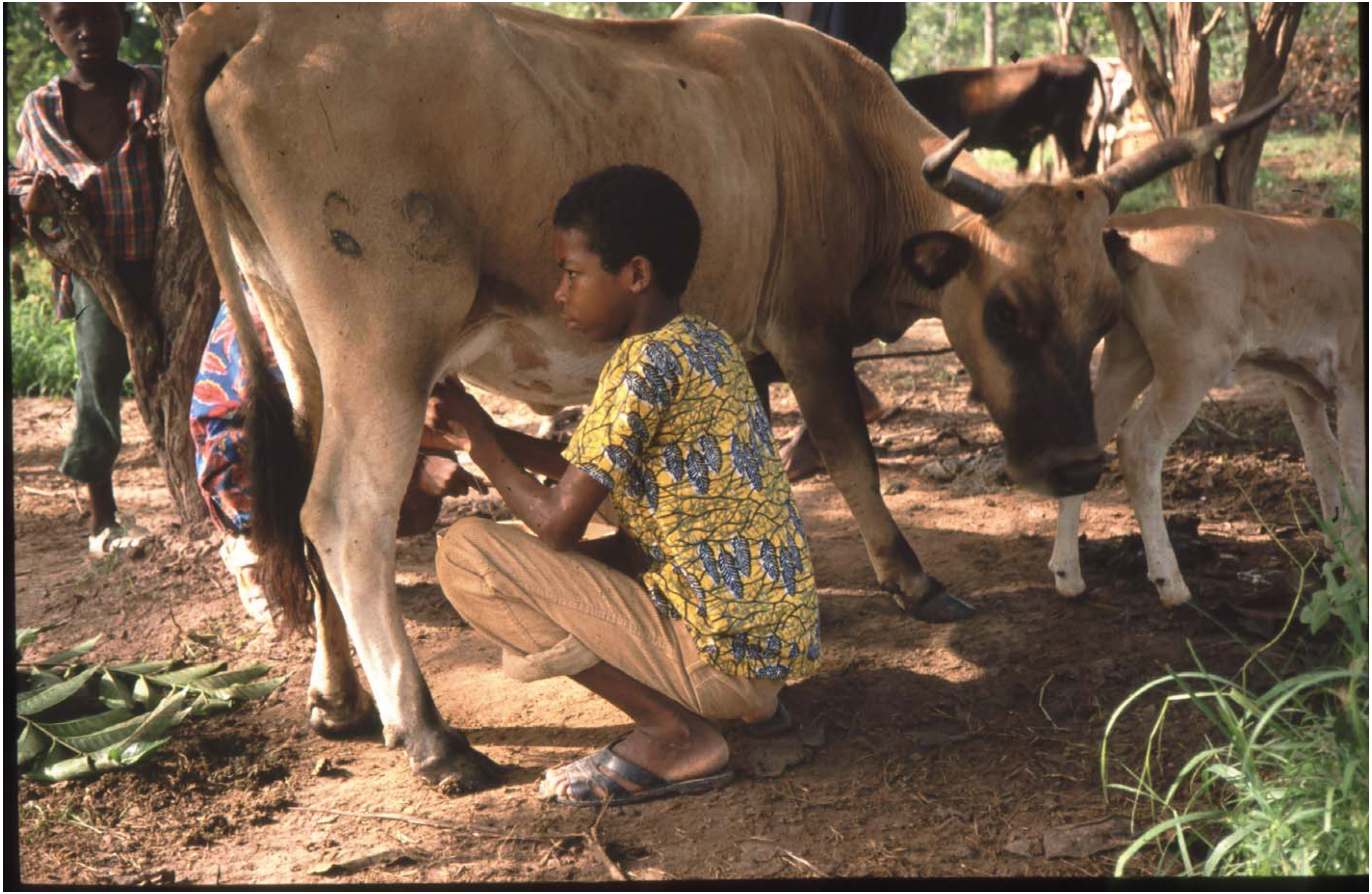
  - what the breed looks like

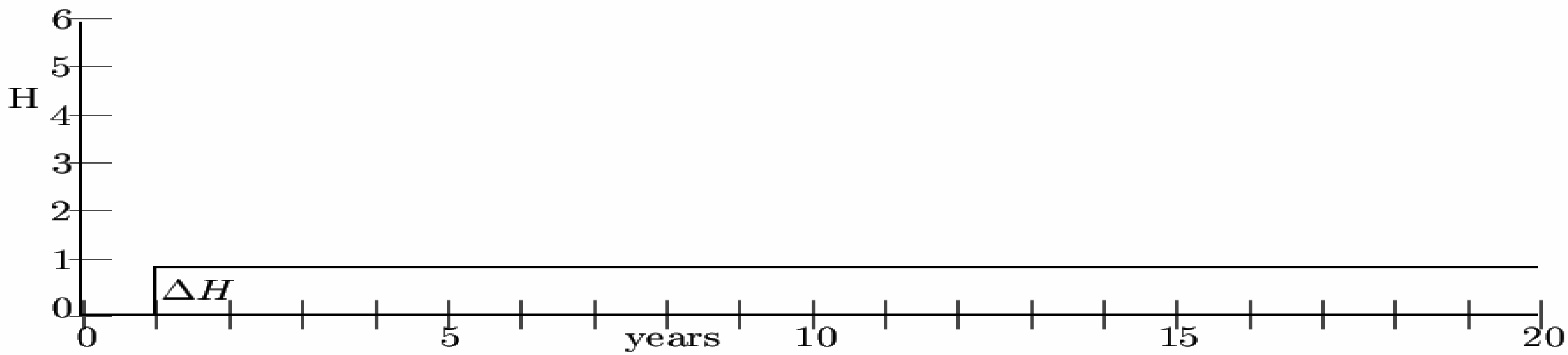
  - what it is used for

  - what is the fodder for several months

  - what is the fodder for the rest of the year

  - What do we need for calculating the Net Present Value (NPV)





$$NPV(0) = -c_o + \frac{\Delta H \cdot N}{(1+i)^2} + \frac{\Delta H \cdot N}{(1+i)^3} + \frac{\Delta H \cdot N}{(1+i)^4} + \cdots + \frac{\Delta H \cdot N}{(1+i)^k} + \cdots$$

$$NPV(0) = -c_o + \frac{\Delta H \cdot N}{(1+i)^2}[1 + (\frac{1}{1+i})^1 + (\frac{1}{1+i})^2 + (\frac{1}{1+i})^3 + \cdots + (\frac{1}{1+i})^{T-2}]$$

$$= -c_o + \Delta H \cdot N \frac{1}{i(1+i)}[1 - (\frac{1}{1+i})^{T-1}]$$

- How to determine ΔH?

  For this we need the marginal profits.

- Take a typical herd of about 80 animals (about 30 cow) and stock it with average animals.
- Determine the needed metabolizable energy, the costs, the returns and profit.
- Stock it with identical animals except for one trait
- What difference do we have in profit?

  That marginal profit can be standardized

- Some characteristics of the N‘Dama

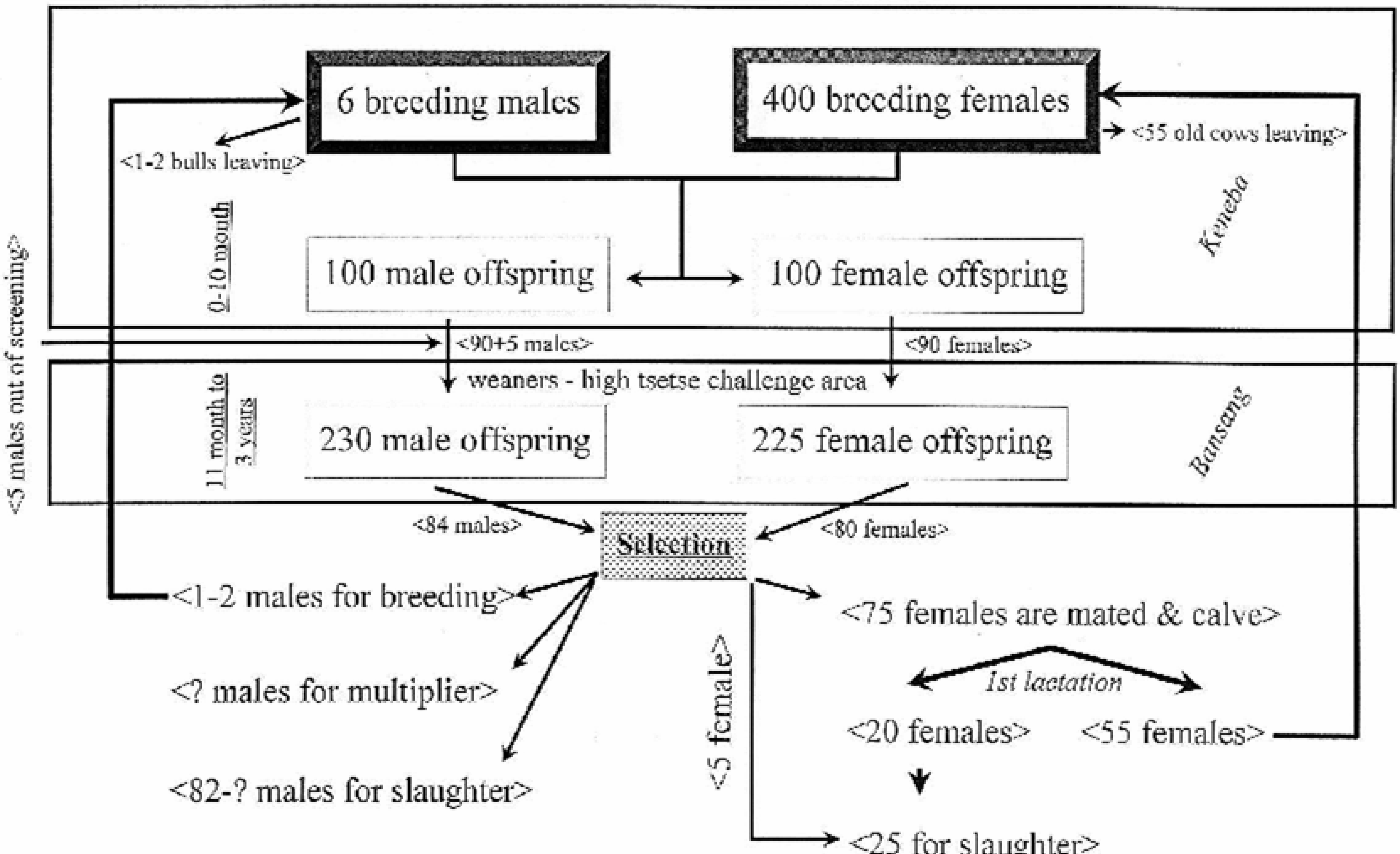
Age at first calving:	4-5 years
Age of bulls at birth of progeny:	4-5 years
Calving interval:	2 years
Number of calvings	4-5
Female adult body weight (av.):	200-240 kg
Lactation milk off-take:	350 kg
Calving is weakly seasonal	July-Nov.

- What kind of Multiplier do we need without AI?

- Assume that the Nucleus produces annually 96 males for selection
- A breeding bull mates 50 cows annually
- A bull is at most used 4 years
- Nucleus needs two bulls and 46 bulls can go to multiplier annually
- The 184 bulls in Multiplier serve 18 400 cows
- Multiplier produces 3680 bulls a year
- Sufficient for nearly 1.5 Mill cows or a cattle population of nearly 4 Mill animals

Next slide shows an example of the nucleus

Figure 2: Cattle Nucleus Breeding Scheme (simplified)
< ... > annual movement, other numbers are stock numbers



- Some details about the Nucleus
- Age distribution of cows

age in years: 4 5 6 7 8 9 10

Numbers: **96** 65 **58** 53 **47** 43 **38** | 400

Calvings: 240

Genetic parameters for dg (g) and milk(kg)

$$\mathbf{V}_A = \begin{bmatrix} 2430 & -517.6 \\ -517.6 & 1225 \end{bmatrix} \qquad \mathbf{V}_P = \begin{bmatrix} 8100 & 0 \\ 0 & 4900 \end{bmatrix}$$

Definition of H:

$$H = a_1\ g_{dg\ in\ g} + a_2\ g_{\text{milk kg}} = 0.2165 g_{dg} + 0.5187 g_{\text{milk}}$$

$\sigma_H = 18.09$ ($\sigma_{H_w} = 15.661$ for within sire selection).

- Next slides show the
  - Time schedule
  - Equations for following genetic progress in the nucleus
  - Equations for following genetic progress in the whole genetic improvement scheme (following strictly Nucleus -> Multiplier -> Commercial)
  - Graph of genetic levels
  - Equations for following genetic progress in the whole genetic improvement scheme (some males go from nucleus directly to the commercial units)+Graph of genetic levels

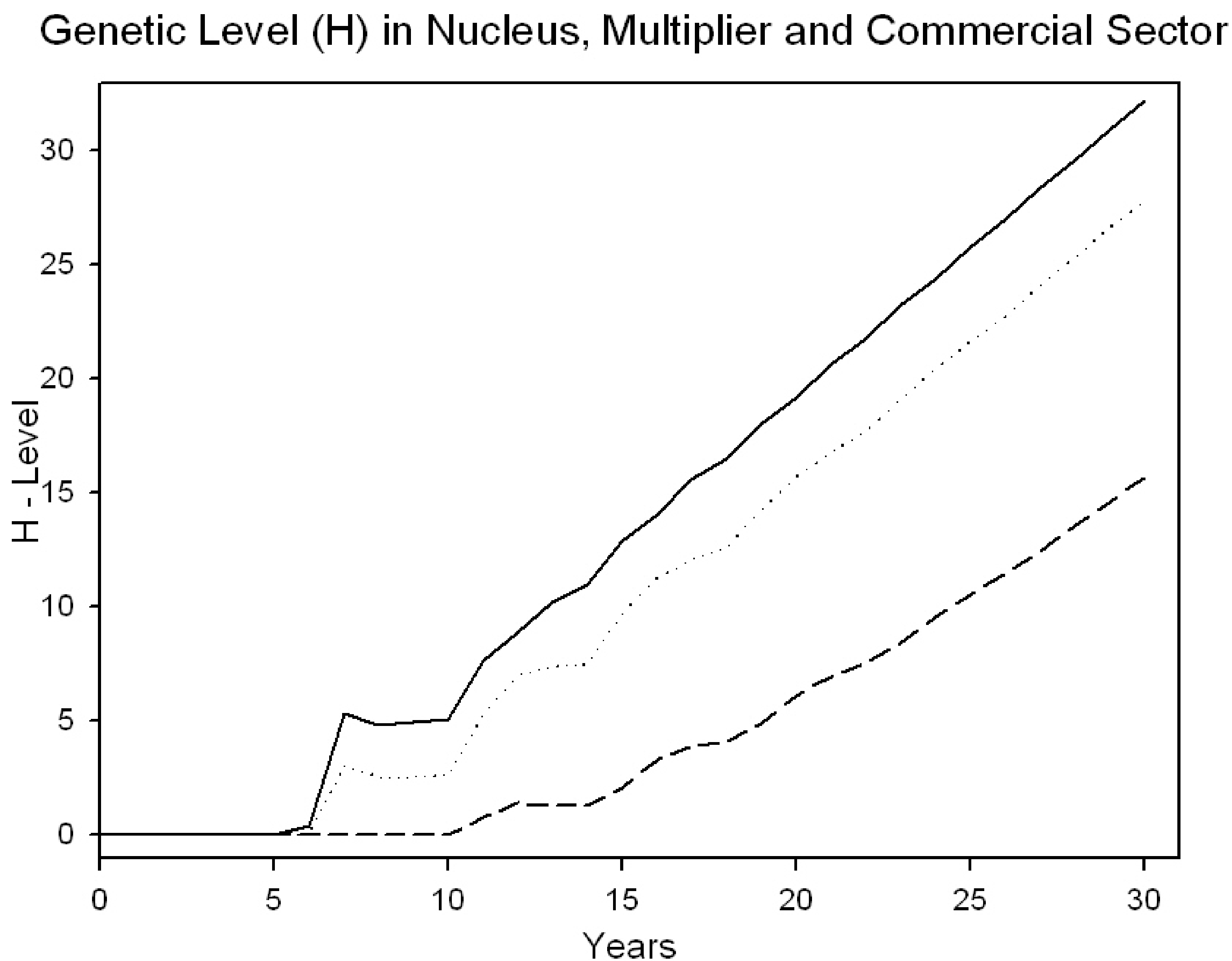
dg: daily gain; my: milk yield; c: candidate; d: dam; s: sire; hs: paternal half sisters.

Time	**Action**
2006	Start of programme
	Identification of all animals
	Parentage recording (only dam) of calves born 2005 and 2006
	Recording of milk, weight, mating, birth, exit, disease
	Use of all cows and of identified random bulls
2007	Parentage recording (sire and dam) of new born calves
	Recording of milk, weight, mating, birth, exit, disease, parentage
	Selection of heifers (born 2002) on c: my
	Use of partially **selected cows** (based on first lactation) in Nucleus
	Use of identified random bulls
2008	Recording of milk, ..., parentage
	Selection of heifers (born 2003) on c: my
	Selection of heifers (born 2005) on c: dg, d: my to be mated for producing bulls
	Selection (unrestricted) of young bulls (born 2005) on c: dg, d: my
	Offspring of partially selected cows born
	Use of partially selected cows in Nucleus
	Use of selected bulls (born 2005) in **Nucleus** and **Multiplier**
2009	Recording of milk, ..., parentage
	Selection of heifers (born 2004) on c: my
	Selection of heifers (born 2006) on c: dg, d: my to be mated for producing bulls
	Selection (restricted) of bulls (born 2006) on c: dg, d: my
	Offspring of selected parents born
	Use of selected cows in Nucleus
	Use of selected bulls in Nucleus and Multiplier
2010	as 2009 but selection of heifers (born 2005) on c: dg my, d: my
2011	as 2010
2012	as 2010 but selection of heifers (born 2007) on c: dg my, d: my, hs: dg my
2013	as 2012
2014	Selection of heifers (born 2009) on c: dg my, d: dg my, s: dg, hs: dg my
	Selection of heifers (born 2011) on c: dg, d: dg my s: dg to be mated for producing bulls
	Selection of bulls (born 2011) on c: dg, d: dg my

$$
\overset{2007\,=\,k'\,=\,k+1}{\left[\begin{array}{c}
\mu^{m}_{k'-0}\\ \mu^{m}_{k'-1}\\ \mu^{m}_{k'-2}\\ \mu^{m}_{k'-3}\\ \mu^{m}_{k'-4}\\ \mu^{m}_{k'-5}\\ \mu^{m}_{k'-6}\\ \hline
\mu^{f}_{k'-0}\\ \mu^{f}_{k'-1}\\ \mu^{f}_{k'-2}\\ \mu^{f}_{k'-3}\\ \mu^{f}_{k'-4}\\ \mu^{f}_{k'-5}\\ \mu^{f}_{k'-6}\\ \mu^{f}_{k'-7}\\ \mu^{f}_{k'-8}\\ \mu^{f}_{k'-9}
\end{array}\right]}
=
\left[\begin{array}{ccccccc|cccccccccc}
0&0&0&\ast&\ast&\ast&\ast&0&0&0&\ast&0&\ast&0&\ast&0&\ast\\
1&&&&&&&&&&&&&&&&\\
&1&&&&&&&&&&&&&&&\\
&&1&&&&&&&&&&&&&&\\
&&&1&&&&&&&&&&&&&\\
&&&&1&&&&&&&&&&&&\\
&&&&&1&&&&&&&&&&&\\ \hline
0&0&0&\ast&\ast&\ast&\ast&0&0&0&\ast&0&\ast&0&\ast&0&\ast\\
&&&&&&&1&&&&&&&&&\\
&&&&&&&&1&&&&&&&&\\
&&&&&&&&&1&&&&&&&\\
&&&&&&&&&&1&&&&&&\\
&&&&&&&&&&&1&&&&&\\
&&&&&&&&&&&&1&&&&\\
&&&&&&&&&&&&&1&&&\\
&&&&&&&&&&&&&&1&&\\
&&&&&&&&&&&&&&&1&
\end{array}\right]
\overset{2006\,=\,k}{\left[\begin{array}{c}
\mu^{m}_{k-0}\\ \mu^{m}_{k-1}\\ \mu^{m}_{k-2}\\ \mu^{m}_{k-3}\\ \mu^{m}_{k-4}\\ \mu^{m}_{k-5}\\ \mu^{m}_{k-6}\\ \hline
\mu^{f}_{k-0}\\ \mu^{f}_{k-1}\\ \mu^{f}_{k-2}\\ \mu^{f}_{k-3}\\ \mu^{f}_{k-4}\\ \mu^{f}_{k-5}\\ \mu^{f}_{k-6}\\ \mu^{f}_{k-7}\\ \mu^{f}_{k-8}\\ \mu^{f}_{k-9}
\end{array}\right]}
+
\left[\begin{array}{c}
0.5(\Delta G^{k}_{mm}+\Delta G^{k}_{fm})\\ 0\\ 0\\ 0\\ 0\\ 0\\ 0\\ \hline
0.5(\Delta G^{k}_{mf}+\Delta G^{k}_{ff})\\ 0\\ 0\\ 0\\ 0\\ 0\\ 0\\ 0\\ 0\\ 0
\end{array}\right]
$$

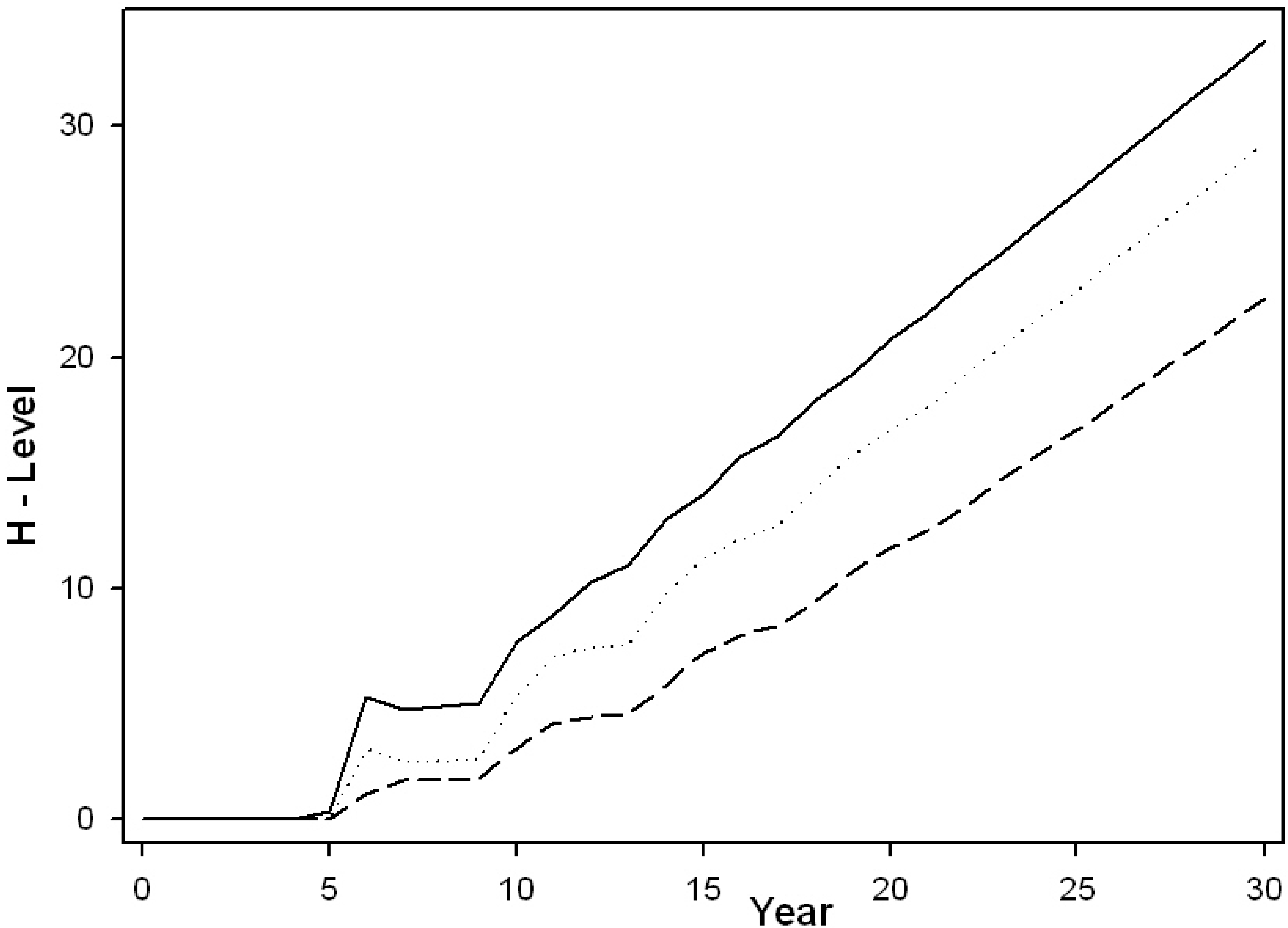
$$
\boldsymbol{\mu}_{\boldsymbol{k'}} \quad = \quad \mathbf{M} \quad \boldsymbol{\mu}_{\boldsymbol{k}} \quad + \quad \boldsymbol{\Delta G_k}
$$

$$\left[\begin{array}{c} \mu^{m}_{N\ k'} \\ \mu^{f}_{N\ k'} \\ \hline \mu^{m}_{M\ k'} \\ \mu^{f}_{M\ k'} \\ \hline \mu^{m}_{C\ k'} \\ \mu^{f}_{C\ k'} \end{array}\right] = \left[\begin{array}{cc|cc|cc} \mathsf{M}_{NN\ mm} & \mathsf{M}_{NN\ fm} & \mathsf{0} & \mathsf{0} & \mathsf{0} & \mathsf{0} \\ \mathsf{M}_{NN\ mf} & \mathsf{M}_{NN\ ff} & \mathsf{0} & \mathsf{0} & \mathsf{0} & \mathsf{0} \\ \hline \mathsf{M}_{NM\ mm} & \mathsf{0} & \mathsf{0} & \mathsf{M}_{MM\ fm} & \mathsf{0} & \mathsf{0} \\ \mathsf{M}_{NM\ mf} & \mathsf{0} & \mathsf{0} & \mathsf{M}_{MM\ ff} & \mathsf{0} & \mathsf{0} \\ \hline \mathsf{0} & \mathsf{0} & \mathsf{M}_{MC\ mm} & \mathsf{0} & \mathsf{0} & \mathsf{M}_{CC\ fm} \\ \mathsf{0} & \mathsf{0} & \mathsf{M}_{MC\ mf} & \mathsf{0} & \mathsf{0} & \mathsf{M}_{CC\ ff} \end{array}\right] \left[\begin{array}{c} \mu^{m}_{N\ k} \\ \mu^{f}_{N\ k} \\ \hline \mu^{m}_{M\ k} \\ \mu^{f}_{M\ k} \\ \hline \mu^{m}_{C\ k} \\ \mu^{f}_{C\ k} \end{array}\right] + \left[\begin{array}{c} \Delta G_{N\ .m} \\ \Delta G_{N\ .f} \\ \hline \Delta G_{M\ .m} \\ \Delta G_{M\ .f} \\ \hline 0 \\ 0 \end{array}\right]$$


Genetic Level (H) in Nucleus, Multiplier and Commercial Sector
H - Level
Years
0
5
10
15
20
25
30
0
5
10
15
20
25
30

$$\left[\begin{array}{c}\mu^{m}_{N\ k'}\\ \mu^{f}_{N\ k'}\\ \hline \mu^{m}_{M\ k'}\\ \mu^{f}_{M\ k'}\\ \hline \mu^{m}_{C\ k'}\\ \mu^{f}_{C\ k'}\end{array}\right] = \left[\begin{array}{cc|cc|cc}\mathsf{M}_{NN\ mm} & \mathsf{M}_{NN\ fm} & 0 & 0 & 0 & 0\\ \mathsf{M}_{NN\ mf} & \mathsf{M}_{NN\ ff} & 0 & 0 & 0 & 0\\ \hline \mathsf{M}_{NM\ mm} & 0 & 0 & \mathsf{M}_{MM\ fm} & 0 & 0\\ \mathsf{M}_{NM\ mf} & 0 & 0 & \mathsf{M}_{MM\ ff} & 0 & 0\\ \hline \mathsf{M}_{NC\ mm} & 0 & \mathsf{M}_{MC\ mm} & 0 & 0 & \mathsf{M}_{CC\ fm}\\ \mathsf{M}_{NC\ mf} & 0 & \mathsf{M}_{MC\ mf} & 0 & 0 & \mathsf{M}_{CC\ ff}\end{array}\right] \left[\begin{array}{c}\mu^{m}_{N\ k}\\ \mu^{f}_{N\ k}\\ \hline \mu^{m}_{M\ k}\\ \mu^{f}_{M\ k}\\ \hline \mu^{m}_{C\ k}\\ \mu^{f}_{C\ k}\end{array}\right] + \left[\begin{array}{c}\Delta G_{N\ .m}\\ \Delta G_{N\ .f}\\ \hline \Delta G_{M\ .m}\\ \Delta G_{M\ .f}\\ \hline \Delta G_{C\ .m}\\ \Delta G_{C\ .f}\end{array}\right]$$

Genetic Level (H) in the Nucleus, Multiplier and Commerial Sector



From year 7 on there is an annual increase of about $\Delta H = 0.65$ and from year 13 on the increase is about $\Delta H = 1.0$.
Much later it goes to the steady state increase of $\Rightarrow 1.3$

Disregarding the smaller increase at the very beginning we get:

$$NPV(0) = -c_o + \frac{N \cdot \Delta H}{(1+i)^7} + \frac{\Delta H \cdot N}{(1+i)^8} + \frac{\Delta H \cdot N}{(1+i)^9} + \cdots + \frac{\Delta H \cdot N}{(1+i)^k} + \cdots$$

$$NPV(0) = -c_o + \frac{N \cdot \Delta H}{(1+i)^7}[1 + (\frac{1}{1+i})^1 + (\frac{1}{1+i})^2 + (\frac{1}{1+i})^3 + \cdots + (\frac{1}{1+i})^{T-7}]$$

$$= -c_o + N \cdot \Delta H \frac{1}{i(1+i)^6}[1 - (\frac{1}{1+i})^{T-6}]$$

$$= -c_o + N \cdot 1.0 \cdot 12.05 = -c_o + N \cdot 12.05 \quad \text{for T = 30, i=0.04}$$

It is profitable if

$$NPV(0) = -c + 12.05\,N > 0$$

If we have realistic figures for c then we can determine how large N (number of animals) must be.

For assessing c, what do we really need for such a breeding scheme**???**

- Performance and pedigree recording
  – Man-power
  – Equipment (scales, milk analyser)
- Additional housing and feeding

  - Bull pens, some additional fencing

  - Supplementary feeding after test
- Logistics

  - 4W Car, Trailer
- Expertise

  - Data management, Estimation of BV

- It is extremely difficult to make general statements of the cost.

  With local expertise I could imagine that an amount of 50 000 € should be sufficient (but not if you have an international expert!).

  That would mean that quite a small affected commercial population would be sufficient.

- Conclusions

  - Assessing the economic of such a breeding scheme is messy!

  - The chosen situation is most unfavorable for the economics (reproduction, generation interval)

  - If this breeding scheme reaches only a small population of animals (not cows) it is justified

Thank You for Attention