Optimizing Breeding Programs

COST-BENEFIT

Cost - Benefit of breeding programs

<u>Cost</u> of breeding programs for genetic improvement

Fixed costs (logistics, scientists etc. etc.)

Cost related to breeding strategy

- cost of phenotyping
- cost of genotyping
- cost of reproduction

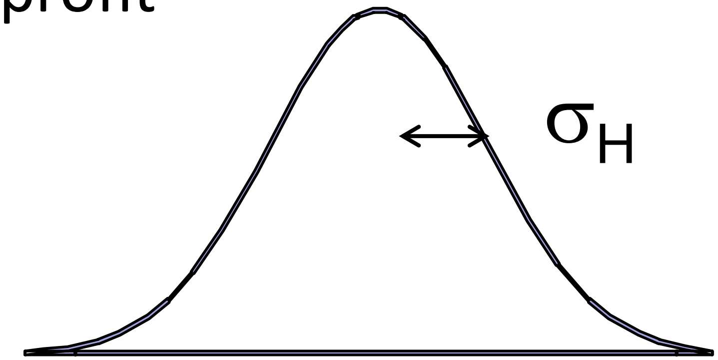
<u>Benefits</u>

Benefit of more genetic gain

Market share

Benefits of genetic gain

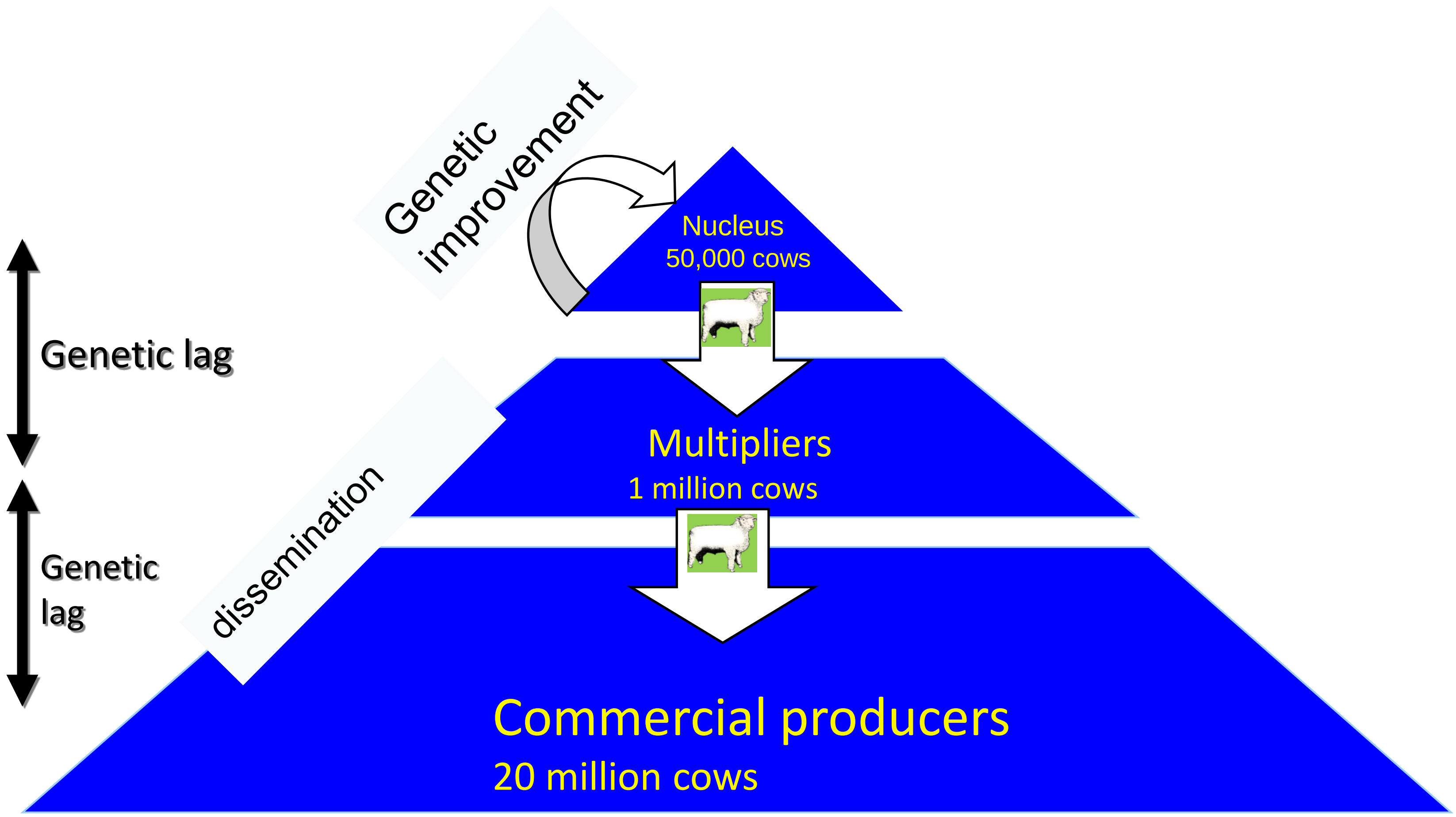
- Assuming the benefit is expressed by the breeding objective (economic values of trait improvement
- Variation in breeding objective is variation in genetic merit for profit



Difference between best and worst is about 6 σ_H

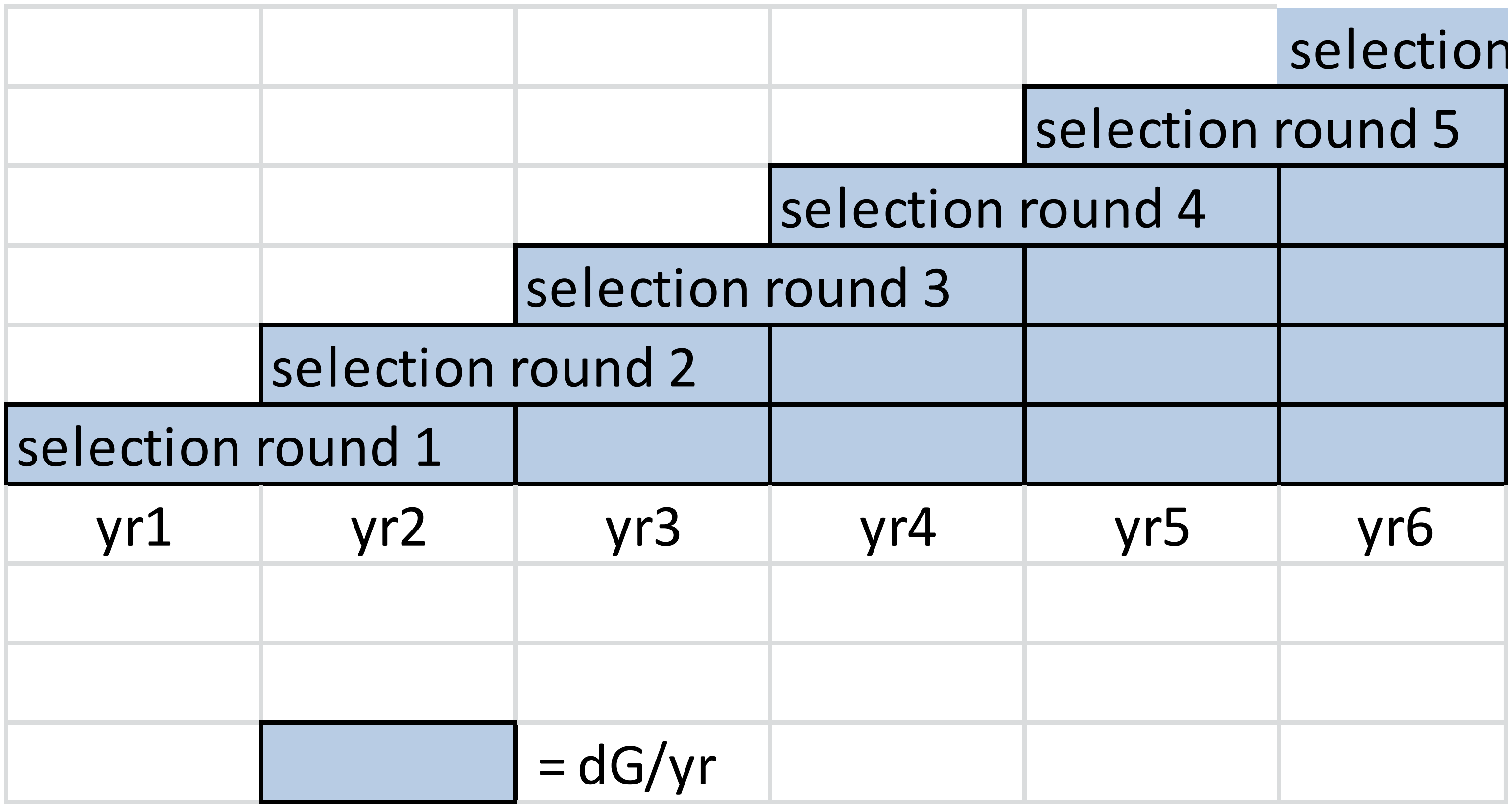
Benefits of genetic gain

- Benefit is transmitted is multiplied over many animals



Benefits of genetic gain

- Benefit is cumulative



Benefits of genetic gain

Benefit is

- Cumulative
- Multiplied over many

Benefits can be expected to be large

- But:
  - Are they achieved?
  - Who gets the benefit?
    - Breeders, Producer? Retail? Consumer?

Economic value of genetic improvement

- Value difference between two bulls
- Value of selecting better bulls
    - Bulls sold to Commercial
    - Bulls used in Stud
- Value of genetic improvement – whole herd

Two Commercial Bulls

	<u>EBV YWT</u>
Bull 1: Kevin	+10 kg
Bull 2: Tony	+15 kg

Nr Progeny:	100
Value of 1 kg YWT	$4
Difference in progeny	2.5 kg

Difference in value: as commercial bulls	5*$4	* 100	* 0.5
	Selection Difference	Nr of Progeny	Expression per progeny

= $1000.-

Two Commercial Bulls

	<u>$Index</u>
Bull 1: Kevin	+190
Bull 2: Tony	+180

Nr Progeny: 100

Difference in progeny $5

Difference in value:	$10	* 100	* 0.5
as commercial bulls	Selection Difference	Nr of Progeny	Expression per progeny

= $500.-

Selecting Better Bulls

		$Index
Average of 100 rams sold:	With Genomics	+182
	No Genomics	+180

Nr Progeny: 100 per bull

Difference in progeny $1.0

Difference in value: as commercial bulls	$2	* 100	* 0.5
	Selection Difference	Nr of Progeny	Expression per progeny

= $100.- * 100 rams = $10,000.

So principles are

Value of a superior bull

= Selection Difference * Nr.Progeny * expressions per progeny

We look at all expressions in <u>commercial</u> progeny

To evaluate benefit we need to predict

- the extra Selection Difference we can get

  this will depend a lot on extra accuracy

- the number of expressions

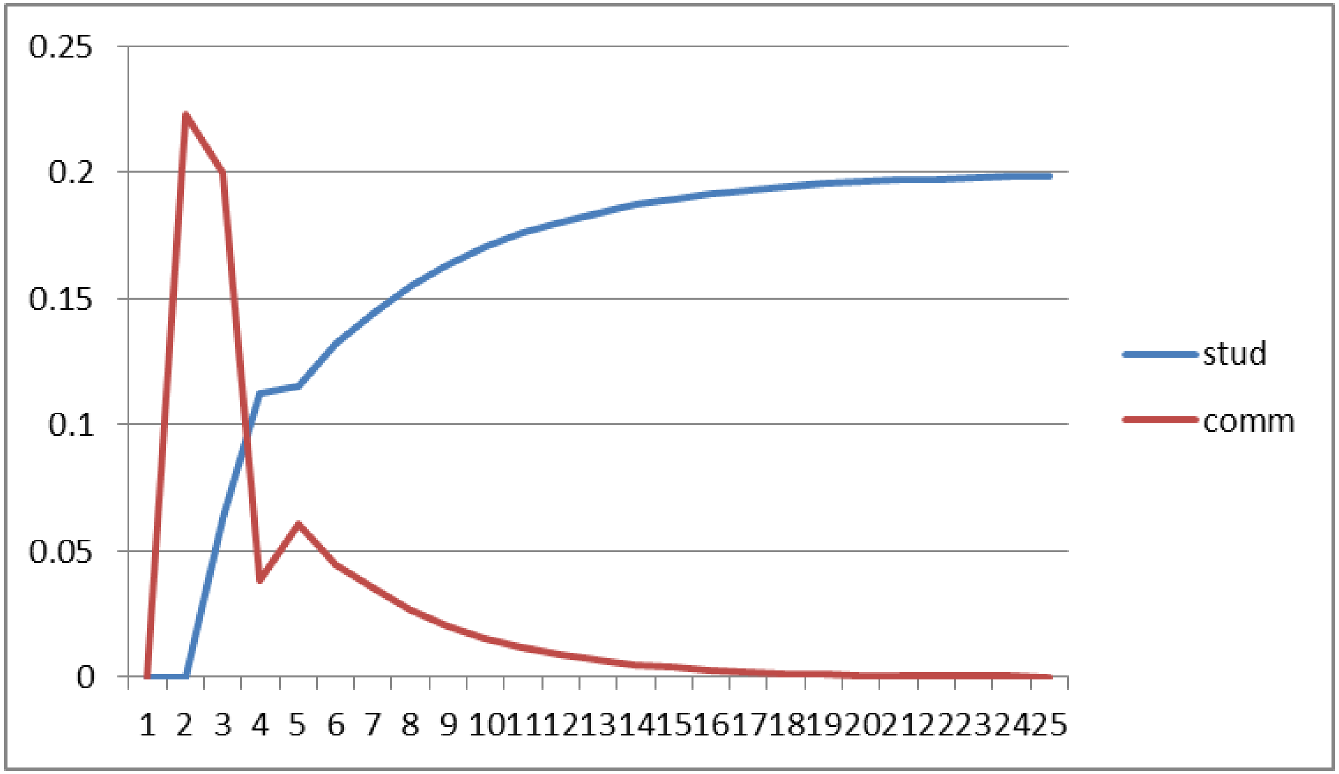
How about selection of stud bulls?

Value of a superior bull

= Selection Difference * Nr.Progeny * expression per progeny

Progeny in commercial, so for a stud bulls
these are actually
grand progeny,
great grand progeny, etc

(allele) frequency of one unit of superiority as expressed in commercial herd



The fate of superiority from commercial bull vs a stud bull

Noting that a commercial bull also transmits the superiority from a stud bull

GENEFLOW

Predict more precisely when benefits occur

males to males	females to males
males to females	females to females

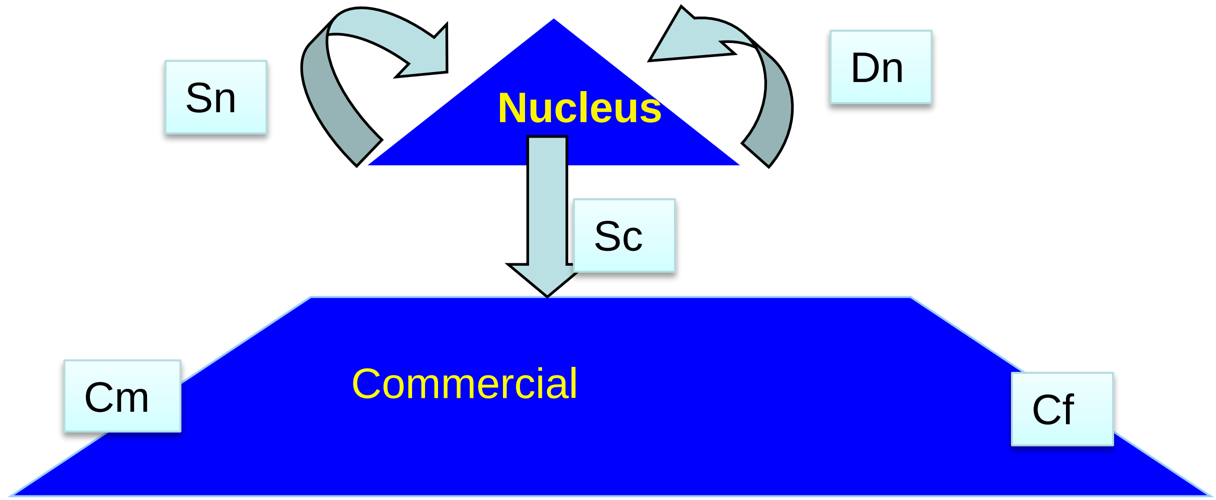
Donors of genes

Recipients of genes

	Sires of Nucleus					Dams of Nucleus									
P matrix	1	2	3	4	5	1	2	3	4	5	6	7	8	9	10
1	0	0.5	0	0	0	0	0.166667	0.166667	0.166667	0	0	0	0	0	0
2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
5	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
1	0	0.5	0	0	0	0	0.166667	0.166667	0.166667	0	0	0	0	0	0
2	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
7	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
8	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
9	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
10	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0

nes

GENEFLOW



Donors of genes

Recipients of genes

	Sn	Dn	Sc	Cm	Cf
Sn	Sn<Sn	Sn<Dn	Sn<Sc	Sn<Cm	Sn<Cf
Dn	Dn<Sn	Dn<Dn	Sf<Sc	Dn<Cm	Dn<Cf
Sc	Sc<Sn	Sc<Dn	Sc<Sc	Sc<Cm	Sc<Cf
Cm	Cm<Sn	Cm<Dn	Cm<Sc	Cm<Cm	Cm<Cf
Cf	Cf<Sn	Cf<Dn	Cf<Sc	Cf<Cm	Cf<Cf

Sn	Sires of Nucleus
Dn	Dams of Nucleus
Sc	Stud born males to sire commercial
Cm	Commercial born males
Cf	Commercial born females

GENEFLOW

Donors of genes

Sn · Dn · Sc · Cm · Cf

Recipients of genes

donors of genes

		Sires of Nucleus					Dams of Nucleus										Stud born males to sire commercial					Commercial born males					Commercial born females									
	P matrix	1	2	3	4	5	1	2	3	4	5	6	7	8	9	10	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	6	7	8	9	10
recipients of genes	1	0	0.5	0	0	0	0	0.166667	0.166667	0.166667	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	3	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	4	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	5	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	1	0	0.5	0	0	0	0	0.166667	0.166667	0.166667	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	2	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	3	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	4	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	5	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	6	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	7	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	8	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	9	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	10	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	1	0	0.5	0	0	0	0	0.166667	0.166667	0.166667	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.5	0	0	0	0	0	0	0	0	0	0.166667	0.166667	0.166667	0	0	0	0	0	0
	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.5	0	0	0	0	0	0	0	0	0	0.166667	0.166667	0.166667	0	0	0	0	0	0
	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
	9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0

P = matrix describing transmission of genes

GENEFLOW

- R = a matrix defining gene transmission of some superiority (or particular allele)

Sn

Dn

- Q= a matrix describing aging

Sn

	Sires of Nucleus					Dams of Nucleus			
P matrix	1	2	3	4	5	1	2	3	4
1	0	0.5	0	0	0	0	0.166667	0.166667	0.166667
2	1	0	0	0	0	0	0	0	0
3	0	1	0	0	0	0	0	0	0
4	0	0	1	0	0	0	0	0	0
5	0	0	0	1	0	0	0	0	0
1	0	0	0	0.5	0	0	0.166667	0.166667	0.166667

- P = matrix describing transmission of genes
  - P=R+Q

$$m_t = P\, m_{t-1} + R n_{t-1}$$

- m vector of allele frequency in each age class

- n vector to describe inserting allele or superiority

GENEFLOW

g1	g2	g3	g4	g5	g6	g7	g8	g9	g10	g11	g12	g13	g14	g15	g16	g17	g18	g19	g20	g21	g22	g23	g24	g25
0	0.5	0	0.333333	0.083333	0.305556	0.111111	0.273148	0.138889	0.251543	0.156636	0.236368	0.169496	0.225609	0.178498	0.21805	0.184849	0.212718	0.189324	0.208962	0.192477	0.206315	0.194699	0.20445	0.196265
1	0	0.5	0	0.333333	0.083333	0.305556	0.111111	0.273148	0.138889	0.251543	0.156636	0.236368	0.169496	0.225609	0.178498	0.21805	0.184849	0.212718	0.189324	0.208962	0.192477	0.206315	0.194699	0.20445
0	1	0	0.5	0	0.333333	0.083333	0.305556	0.111111	0.273148	0.138889	0.251543	0.156636	0.236368	0.169496	0.225609	0.178498	0.21805	0.184849	0.212718	0.189324	0.208962	0.192477	0.206315	0.194699
0	0	1	0	0.5	0	0.333333	0.083333	0.305556	0.111111	0.273148	0.138889	0.251543	0.156636	0.236368	0.169496	0.225609	0.178498	0.21805	0.184849	0.212718	0.189324	0.208962	0.192477	0.206315
0	0	0	1	0	0.5	0	0.333333	0.083333	0.305556	0.111111	0.273148	0.138889	0.251543	0.156636	0.236368	0.169496	0.225609	0.178498	0.21805	0.184849	0.212718	0.189324	0.208962	0.192477
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0	0	0.5	0	0.333333	0.083333	0.305556	0.111111	0.273148	0.138889	0.251543	0.156636	0.236368	0.169496	0.225609	0.178498	0.21805	0.184849	0.212718	0.189324	0.208962	0.192477	0.206315	0.194699	0.20445
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0	0	0	0	0.5	0	0.333333	0.083333	0.305556	0.111111	0.273148	0.138889	0.251543	0.156636	0.236368	0.169496	0.225609	0.178498	0.21805	0.184849	0.212718	0.189324	0.208962	0.192477	0.206315
0	0	0	0	0	0.5	0	0.333333	0.083333	0.305556	0.111111	0.273148	0.138889	0.251543	0.156636	0.236368	0.169496	0.225609	0.178498	0.21805	0.184849	0.212718	0.189324	0.208962	0.192477
0	0	0	0	0	0	0.5	0	0.333333	0.083333	0.305556	0.111111	0.273148	0.138889	0.251543	0.156636	0.236368	0.169496	0.225609	0.178498	0.21805	0.184849	0.212718	0.189324	0.208962
0	0	0	0	0	0	0	0.5	0	0.333333	0.083333	0.305556	0.111111	0.273148	0.138889	0.251543	0.156636	0.236368	0.169496	0.225609	0.178498	0.21805	0.184849	0.212718	0.189324
0	0	0	0	0	0	0	0	0.5	0	0.333333	0.083333	0.305556	0.111111	0.273148	0.138889	0.251543	0.156636	0.236368	0.169496	0.225609	0.178498	0.21805	0.184849	0.212718
0	0	0	0	0	0	0	0	0	0.5	0	0.333333	0.083333	0.305556	0.111111	0.273148	0.138889	0.251543	0.156636	0.236368	0.169496	0.225609	0.178498	0.21805	0.184849
0	0	0	0	0	0	0	0	0	0	0.5	0	0.333333	0.083333	0.305556	0.111111	0.273148	0.138889	0.251543	0.156636	0.236368	0.169496	0.225609	0.178498	0.21805
0	0.5	0	0.333333	0.083333	0.305556	0.111111	0.273148	0.138889	0.251543	0.156636	0.236368	0.169496	0.225609	0.178498	0.21805	0.184849	0.212718	0.189324	0.208962	0.192477	0.206315	0.194699	0.20445	0.196265
0	0	0.5	0	0.333333	0.083333	0.305556	0.111111	0.273148	0.138889	0.251543	0.156636	0.236368	0.169496	0.225609	0.178498	0.21805	0.184849	0.212718	0.189324	0.208962	0.192477	0.206315	0.194699	0.20445
0	0	0	0.5	0	0.333333	0.083333	0.305556	0.111111	0.273148	0.138889	0.251543	0.156636	0.236368	0.169496	0.225609	0.178498	0.21805	0.184849	0.212718	0.189324	0.208962	0.192477	0.206315	0.194699
0	0	0	0	0.5	0	0.333333	0.083333	0.305556	0.111111	0.273148	0.138889	0.251543	0.156636	0.236368	0.169496	0.225609	0.178498	0.21805	0.184849	0.212718	0.189324	0.208962	0.192477	0.206315
0	0	0	0	0	0.5	0	0.333333	0.083333	0.305556	0.111111	0.273148	0.138889	0.251543	0.156636	0.236368	0.169496	0.225609	0.178498	0.21805	0.184849	0.212718	0.189324	0.208962	0.192477
0	0	0	0.25	0	0.208333	0.083333	0.229167	0.104167	0.22338	0.138889	0.218557	0.156057	0.214989	0.170332	0.211072	0.179479	0.208424	0.185905	0.206188	0.190297	0.204567	0.193304	0.203333	0.195378
0	0	0	0	0.25	0	0.208333	0.083333	0.229167	0.104167	0.22338	0.138889	0.218557	0.156057	0.214989	0.170332	0.211072	0.179479	0.208424	0.185905	0.206188	0.190297	0.204567	0.193304	0.203333
0	0	0	0	0	0.25	0	0.208333	0.083333	0.229167	0.104167	0.22338	0.138889	0.218557	0.156057	0.214989	0.170332	0.211072	0.179479	0.208424	0.185905	0.206188	0.190297	0.204567	0.193304
0	0	0	0	0	0	0.25	0	0.208333	0.083333	0.229167	0.104167	0.22338	0.138889	0.218557	0.156057	0.214989	0.170332	0.211072						
0	0	0	0	0	0	0	0.25	0	0.208333	0.083333	0.229167	0.104167	0.22338	0.138889	0.218557	0.156057	0.214989	0.170332						
0	0	0	0.25	0	0.208333	0.083333	0.229167	0.104167	0.22338	0.138889	0.218557	0.156057	0.214989	0.170332	0.211072	0.179479	0.208424	0.185905						
0	0	0	0	0.25	0	0.208333	0.083333	0.229167	0.104167	0.22338	0.138889	0.218557	0.156057	0.214989	0.170332	0.211072	0.179479	0.208424						
0	0	0	0	0	0.25	0	0.208333	0.083333	0.229167	0.104167	0.22338	0.138889	0.218557	0.156057	0.214989	0.170332	0.211072	0.179479						
0	0	0	0	0	0	0.25	0	0.208333	0.083333	0.229167	0.104167	0.22338	0.138889	0.218557	0.156057	0.214989	0.170332	0.211072						
0	0	0	0	0	0	0	0.25	0	0.208333	0.083333	0.229167	0.104167	0.22338	0.138889	0.218557	0.156057	0.214989	0.170332						
0	0	0	0	0	0	0	0	0.25	0	0.208333	0.083333	0.229167	0.104167	0.22338	0.138889	0.218557	0.156057	0.214989						
0	0	0	0	0	0	0	0	0	0.25	0	0.208333	0.083333	0.229167	0.104167	0.22338	0.138889	0.218557	0.156057						
0	0	0	0	0	0	0	0	0	0	0.25	0	0.208333	0.083333	0.229167	0.104167	0.22338	0.138889	0.218557						
0	0	0	0	0	0	0	0	0	0	0	0.25	0	0.208333	0.083333	0.229167	0.104167	0.22338	0.138889						
0	0	0	0	0	0	0	0	0	0	0	0	0.25	0	0.208333	0.083333	0.229167	0.104167	0.22338						

0.185905	0.206188	0.190297
0.208424	0.185905	0.206188
0.179479	0.208424	0.185905
0.211072	0.179479	0.208424
0.170332	0.211072	0.179479
0.214989	0.170332	0.211072

Allele frequency in the limit, from on 'insertion' of superiority (or an allele) = $1/(L_m + L_f)$

Geneflow mainly useful for initial part of an action, otherwise can use Rendel and Robertson

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Cumulative Discounted Expressions CDE

Value (V) in year t is worth now V.c where $c=1/(1+d)^t$

d = discount rate

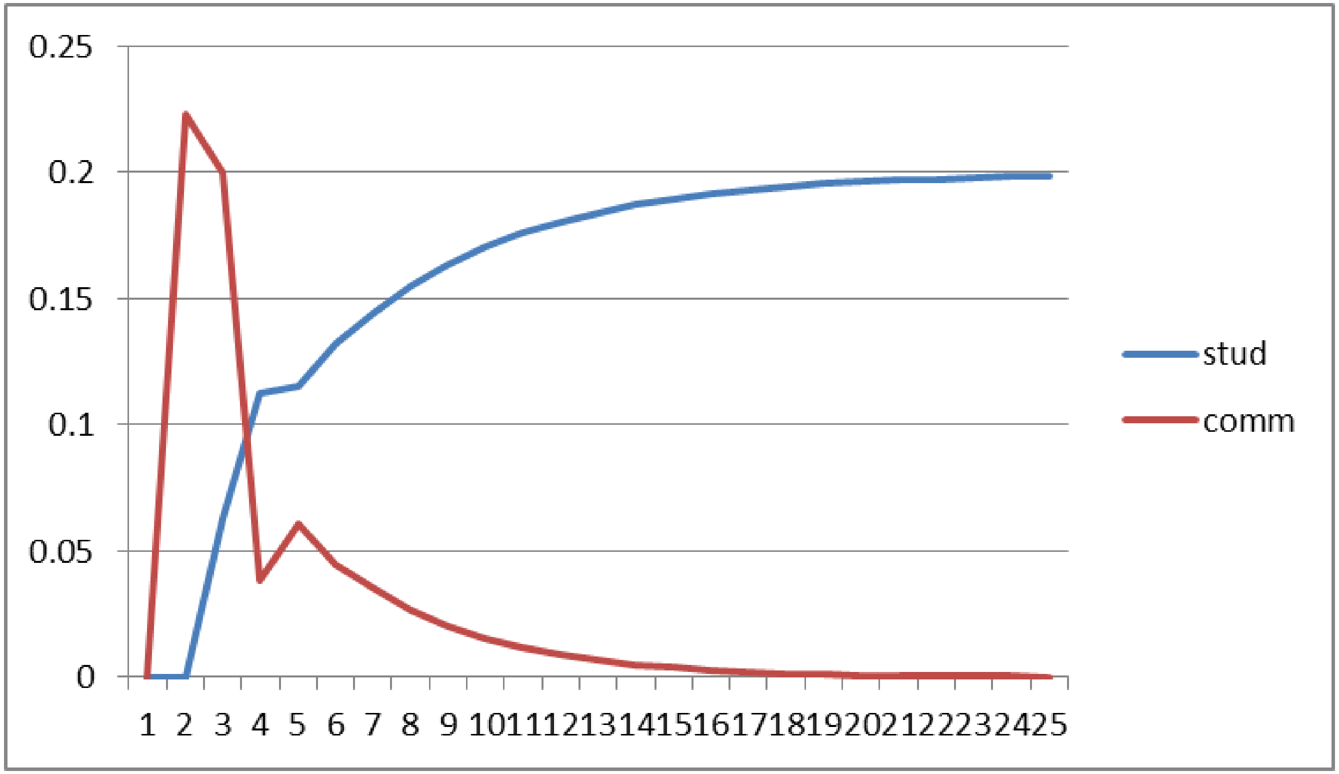
c = discount factor

Expression in age class i in year t is $m(i)_t = E_{it}$

Net Present Value of Sum of expression over 25 years

$$CDE = \sum_{t=1}^{25} \sum_{i=1}^{nac} E_{it} c_t$$

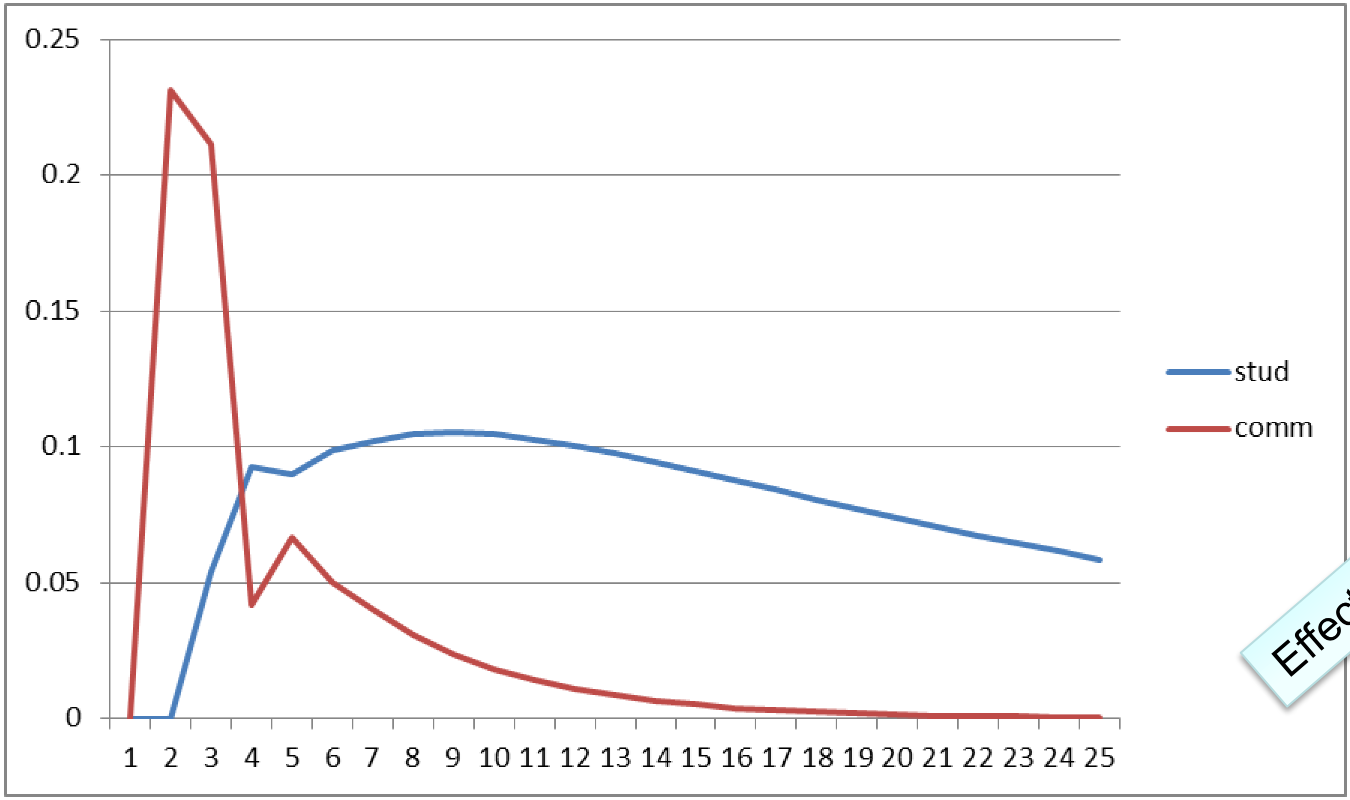
(allele) frequency of one unit of superiority as expressed in commercial herd



The fate of superiority from commercial bull vs a stud bull

Noting that a commercial bull also transmits the superiority from a stud bull ?!

(allele) frequency of one unit of superiority as expressed in commercial herd



Effect of discounting

Discount rate	CDE comm bulls	CDE stud sires
0	0.99	3.93
0.05	0.78	1.96
0.08	0.68	1.37

Sum of all future expressions
Cumulative Discounted Expressions - CDE

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Value of selecting Stud Sires and Comm bulls

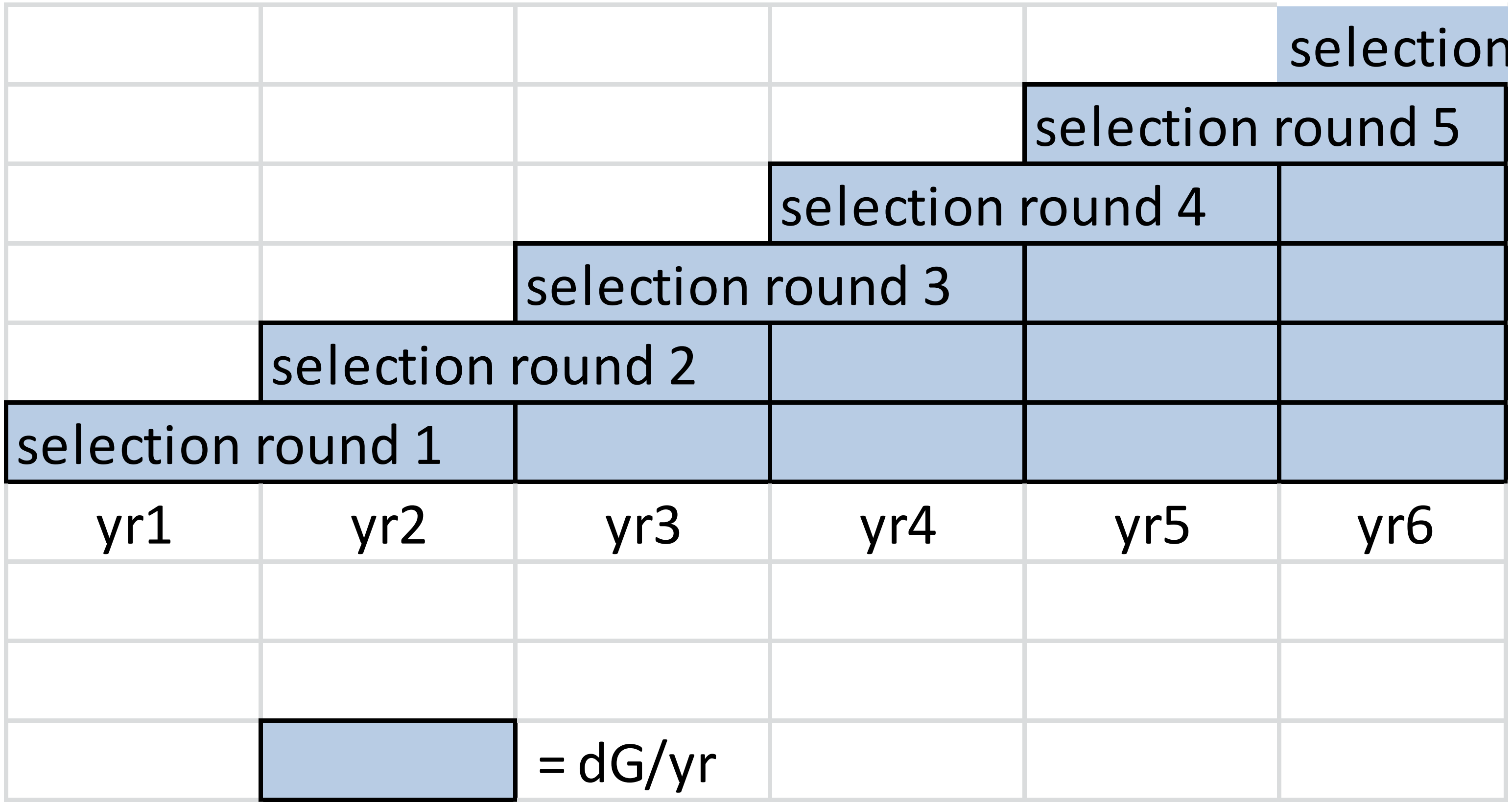
Sum of all future expressions
Cumulative Discounted Expressions

Value of a superior bull

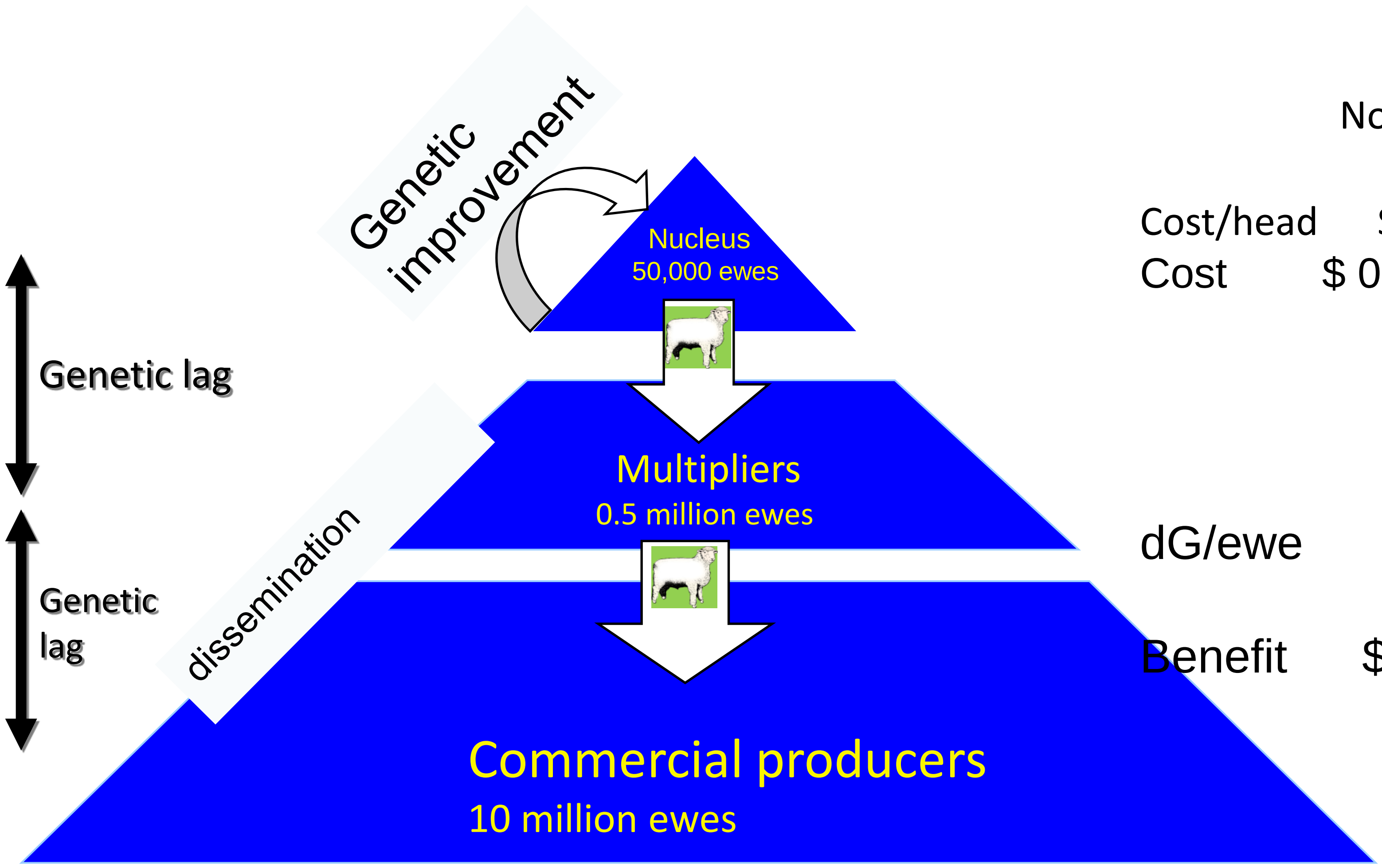
= Selection Difference * Nr.Progeny * expression per progeny

Comm bull	+ 1.4	100	0.68	= $ 95
Stud Sire	+ 3.0	400	1.37	= $ 1,644

Can also use simple method: dG/year, and cumulate



Cost - Benefit of a breeding program



No GS

Cost/head $10

Cost $ 0.5 M

dG/ewe $2

Benefit $20 M

Economic evaluation of breeding programs

Benefit: dG.N accumulates each year

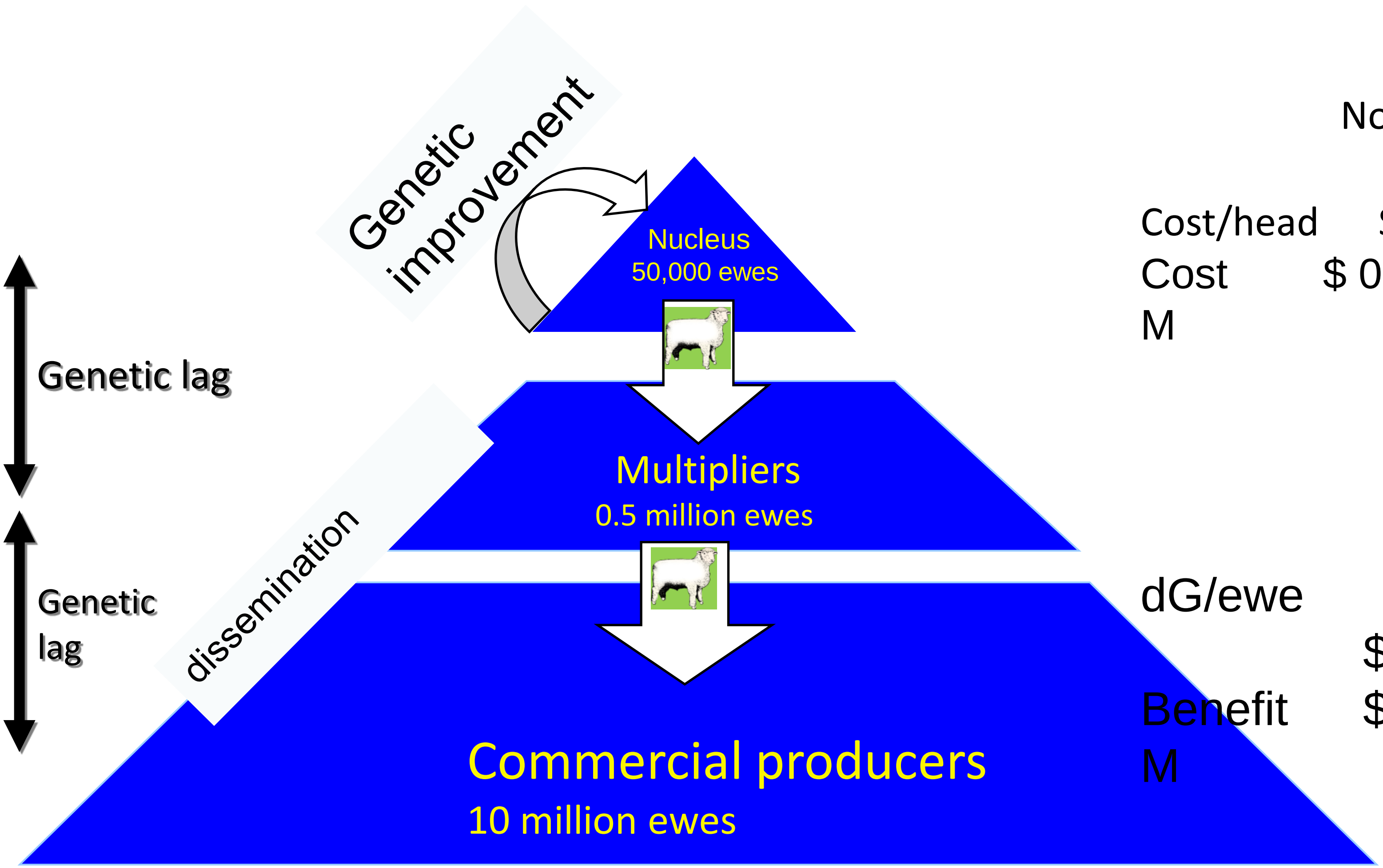
Cost C

Future returns are discounted: $1/r^t$ in year t $(N.t.dG - C).(1/r^t)$

year	Genetic Mean ($)	Benefit (M)	Cost (M)	discount factor	NPV (M$)
1	0	0	0.5	1.00	-0.50
2	1	20	0.5	0.95	18.57
3	2	40	0.5	0.91	35.83
4	3	60	0.5	0.86	51.40
5	4	80	0.5	0.82	65.40
6	5	100	0.5	0.78	77.96
7	6	120	0.5	0.75	89.17
8	7	140	0.5	0.71	99.14

Example:
Comm = 10 Million sheep
dG = $2/head/annum
Cost = 500k

Cost - Benefit of a breeding program



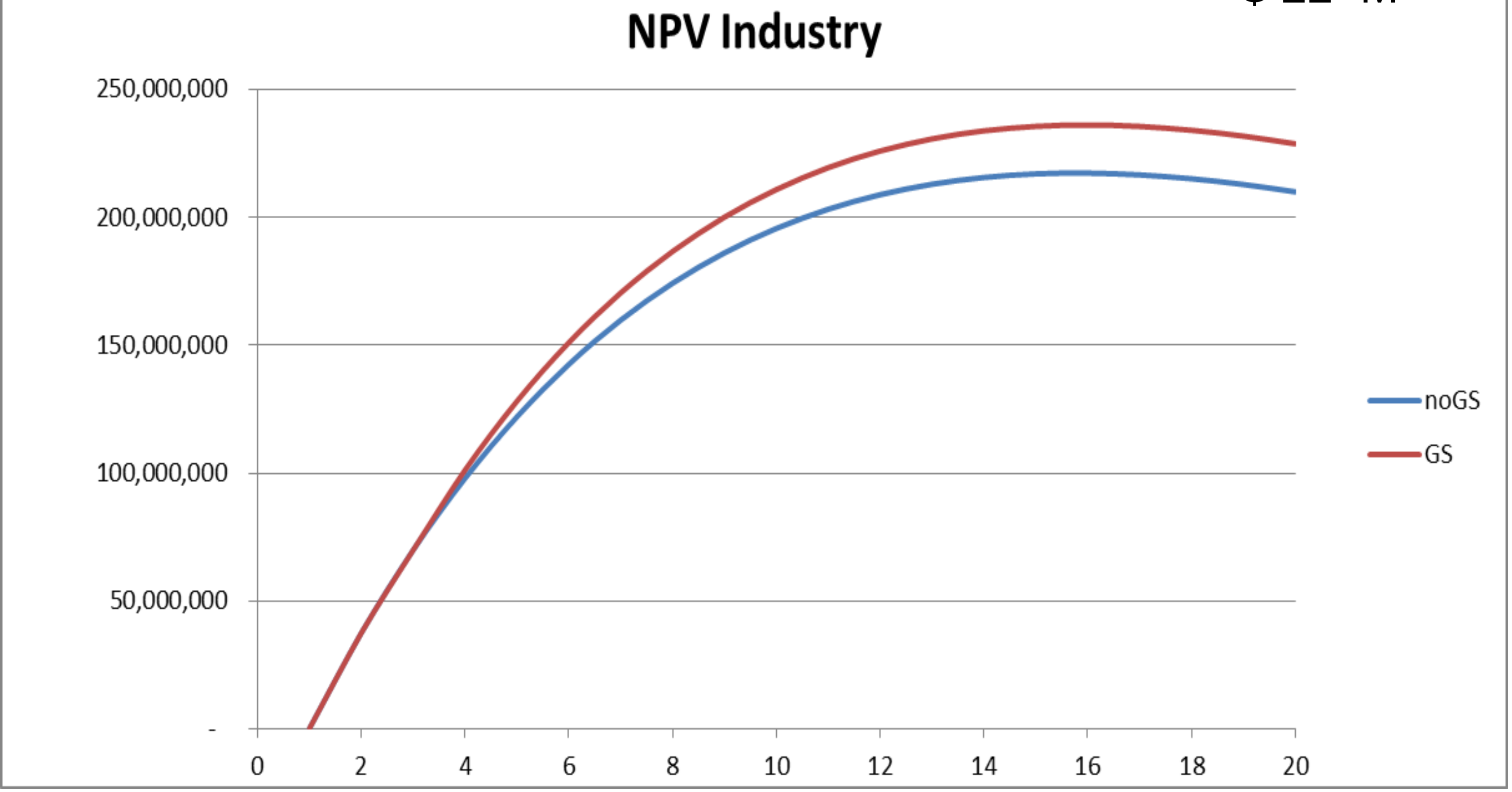
	No GS	With GS
Cost/head	$10	$50
Cost	$ 0.5 M	$ 2.5 M
dG/ewe	$2	$2.2
Benefit	$20 M	$22 M

Cost-Benefit industry wide

3 tier benefit

	No GS	GS
Cost	$0.5 M	$ 2.5 M
dG	$20 M	

$ 22 M

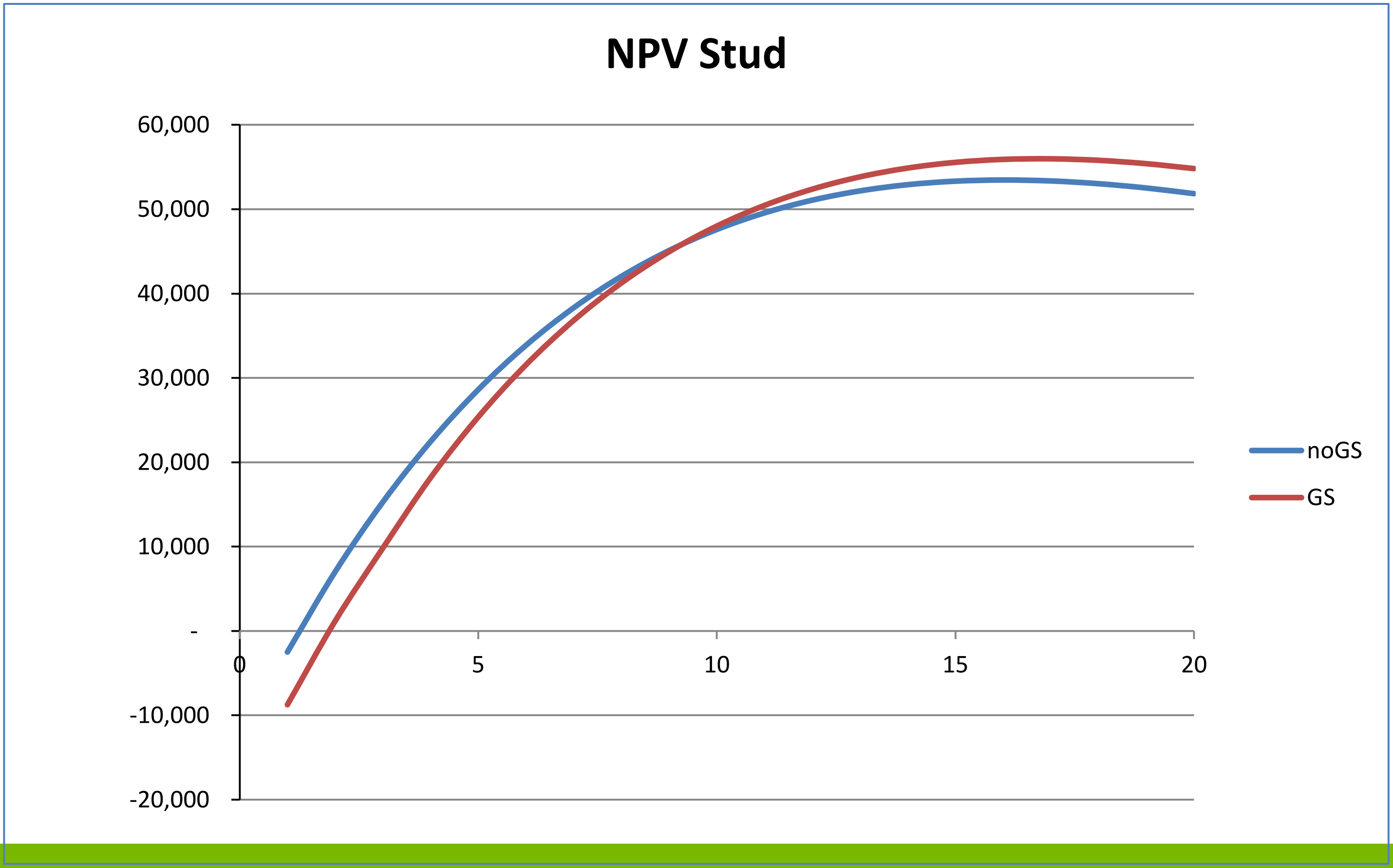


50k Nuc cows
20M Comm

Cost-Benefit Stud

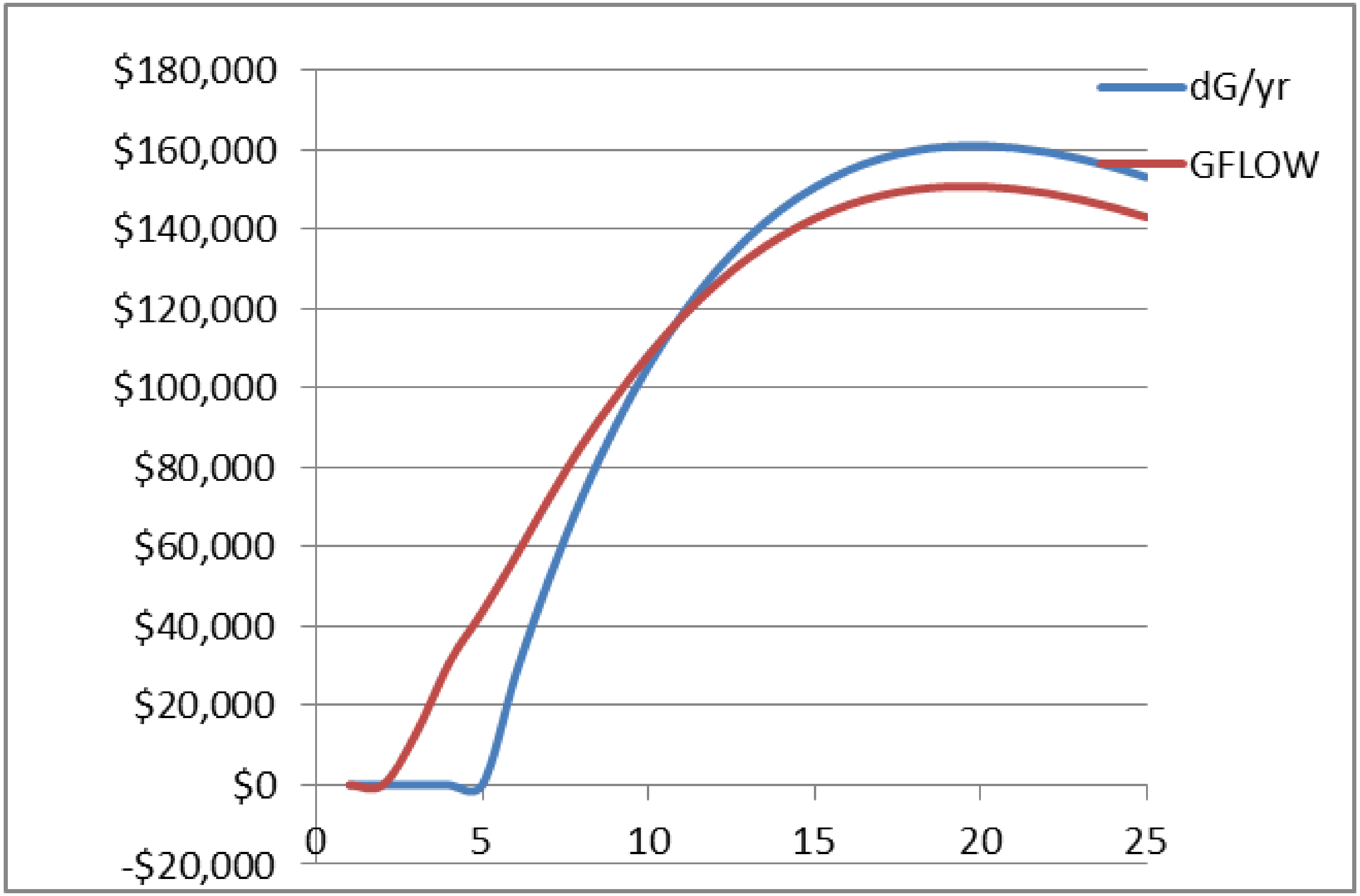
2 tier benefit

	No GS	GS
Cost	$ 5 k	$17.5 k
dG	$20 k	$ 22 k

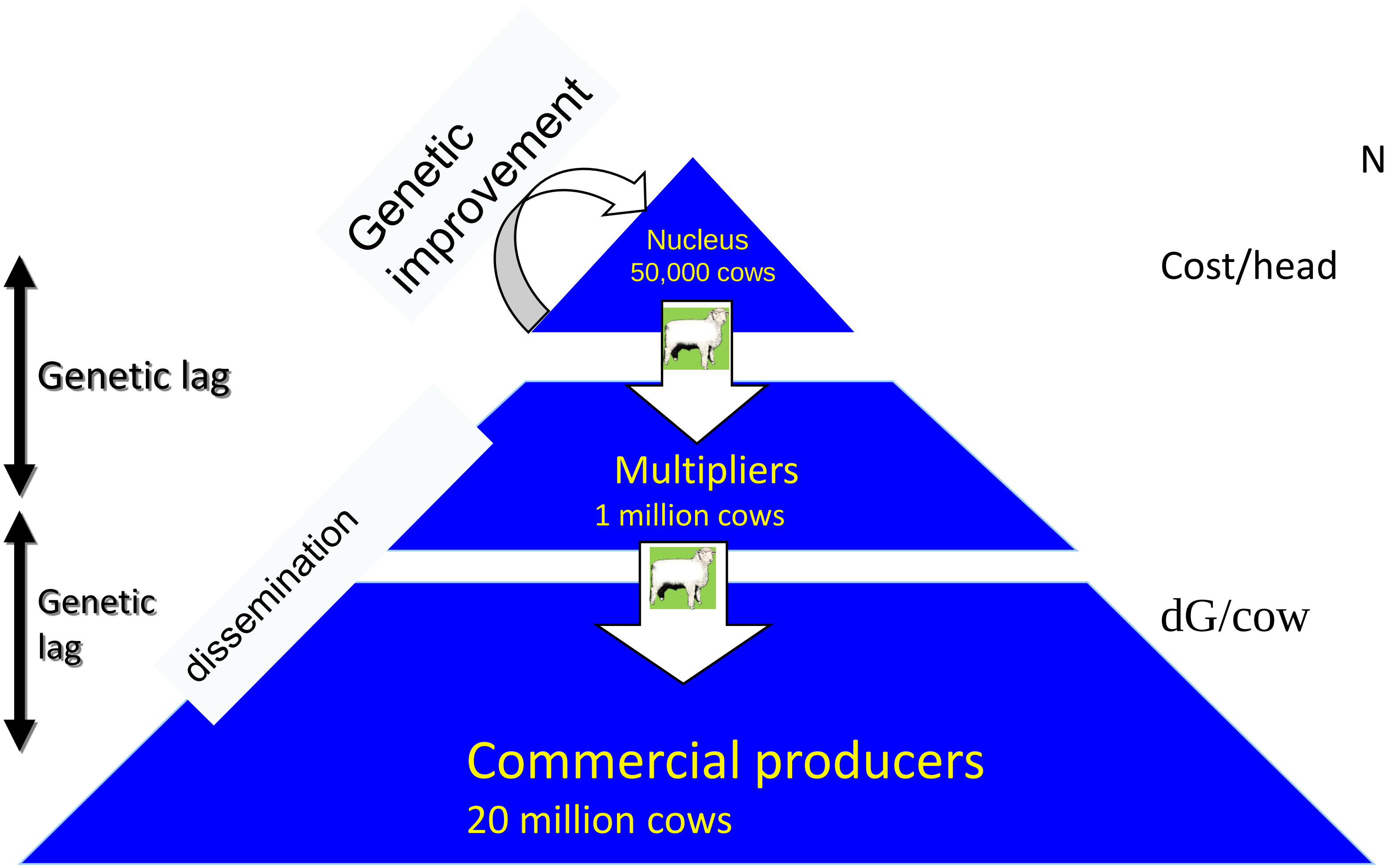


500 Nuc cows
10k Comm

Comparing simply dG/yr vs GFLOW



Cost - Benefit of breeding programs

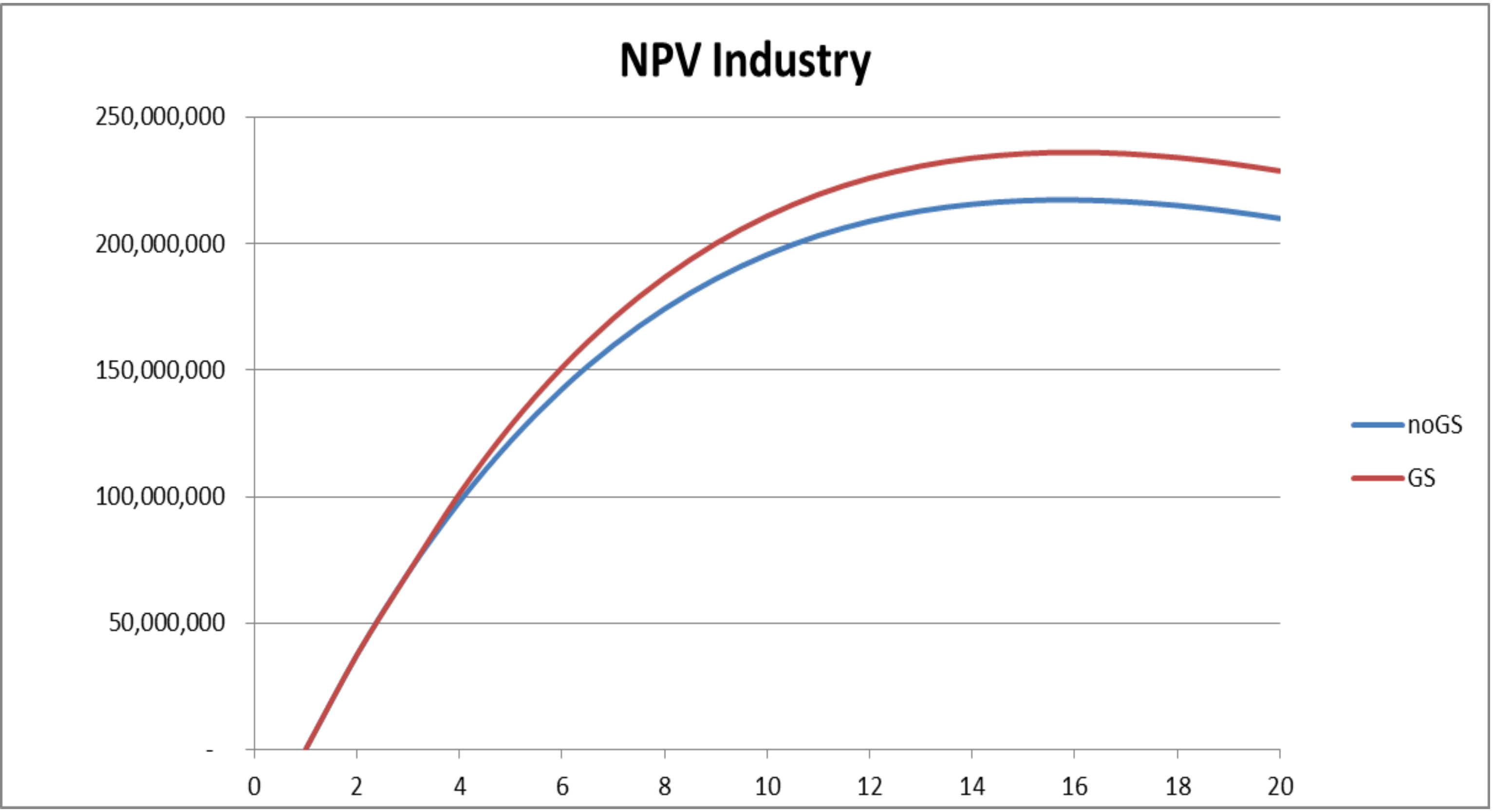


	No GS	GS
Cost/head	$10	$60
dG/cow	$2	$2.2

Cost-Benefit industry wide

3 tier benefit

	No GS	GS
Cost	$0.5 M	$ 1.65 M
dG	$40 M	$ 44 M

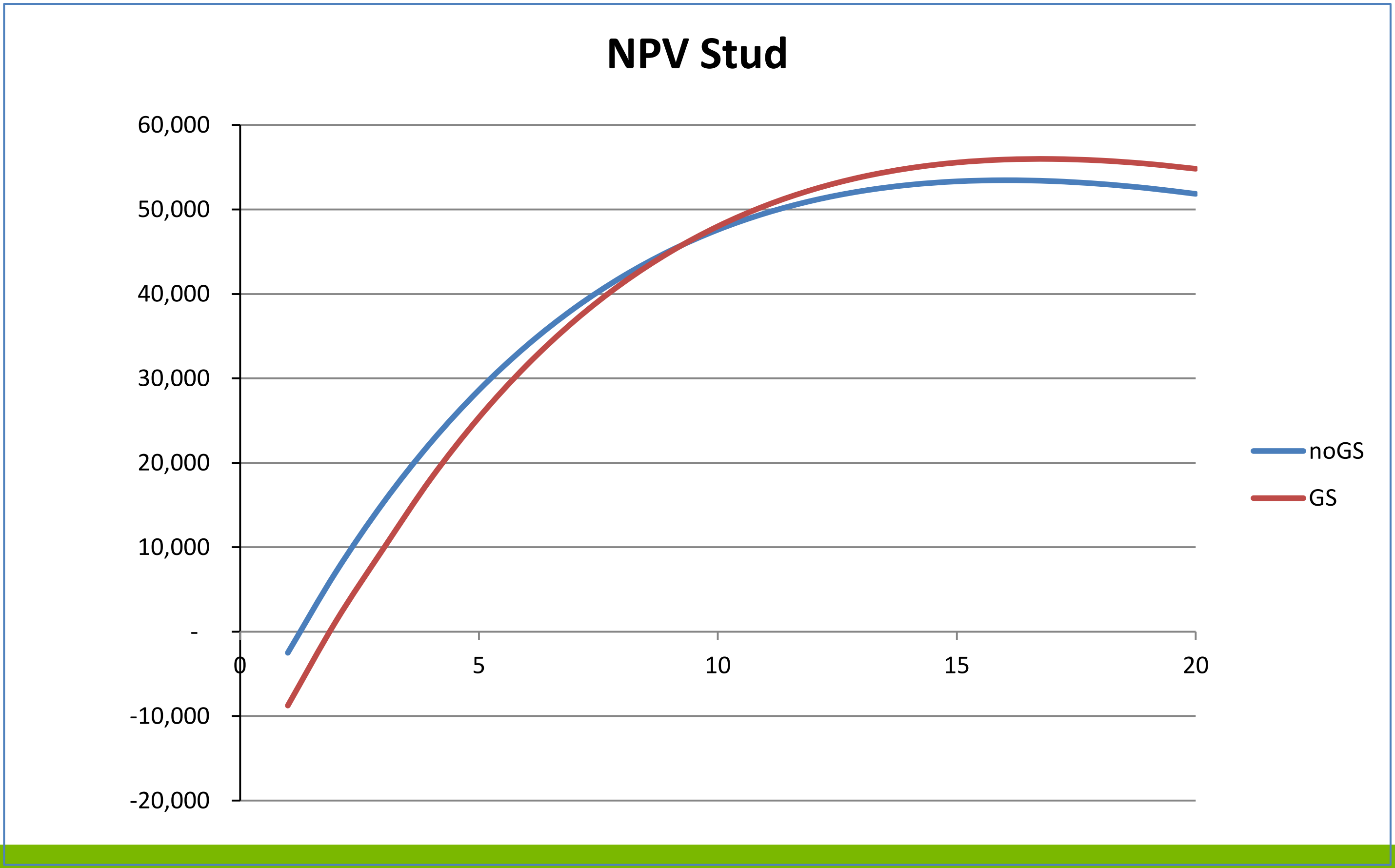


50k Nuc cows
20M Comm

Cost-Benefit Stud

2 tier benefit

	No GS	GS
Cost	$ 5 k	$17.5 k
dG	$20 k	$ 22 k



500 Nuc cows
10k Comm

summary

- Can calculate additional gain on a per bull basis, assuming returns in commercial progeny

- Those figures depend on
  - Additional accuracy
  - Age structure
  - Herd parameters such as weaning rate, mating rate, prop. Sold