Multi-breed Genomic Evaluations for 1 million Beef Cattle in Ireland.

A.R. Cromie, R.D. Evans, J F Kearney, M. McClure, J. McCarthy and D.P. Berry
Overview of Talk.

1. Setting the scene.
2. The Irish Cattle Breeding Industry.
3. The Breeding Goal in Beef.
4. The Irish Beef Genomics Scheme.
   - Overview of the scheme.
   - Technical challenges encountered.
5. Conclusions.
1. What’s important for Ireland?

- **Ag Food Industry.**
  - 9% of GDP. 80% milk & meat are exported.
  - ~5%/annum growth in output.

- **Rural Ireland.**
  - 1.3m dairy & 1m beef cows. 15k dairy & 50k beef farms.

- **“Smart & Green”**
  - Using best science to support indigenous industries.

- **Environment & Climate.**
Agriculture is responsible for 47%, with suckler cows being worst “offenders”!
2. Irish Cattle Breeding.

• Co-ordinated by ICBF.
  - ICBF => a co-operative of 30 cattle breeding organisations (AI, HB + MRO’s) + 2 Farm Organisations.
  - Established the central database in 2002. Now the key cornerstone for Irish AgFood industry.
  - Turnover ~€8m. Funded by industry & government (DAFM).

• Focused on “profit from science”.
  - Key relationship with Teagasc (govt research & extension)
  - Genetics/genomics cornerstone of industry strategy.

• World-leading (research => implementation).
  - 2\textsuperscript{nd} in world to launch dairy genomics, after US.
  - Beef Genomics => largest livestock genomics project globally.
Vets & vet labs.

Genotypes & gen labs.

ICBF Database

Teagasc Research Schemes, e.g., BVD, BGDP, Origin Green

Slaughter Factories

Herd Books

AI Companies

Milk Recording

Herd Books

DAFF - AIM

Factories

Milk Co-ops

Teagasc ACA Advisors

Marts & auctioneers

700k MR recs/yr

7.0 m movement records/yr

1m AI recs/yr

1.6 m carcass recs/yr

100k farmers are now serviced from the database.

30m animals with 100m+ records.

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30m animals with 100m+ records.
IDB Chip – The database in 54k SNP’s!

• The International Dairy & Beef Chip.
• Developed in Ireland, with Illumina. Currently on v3.
• 54k SNP’s.
  • 40k core, 6k for better imputation, 7k for “regions of interest” & 1k for major genes/defects.
• 160 Major genes/defect.
  • Database will drive this.
• V4+ - use of sequence data.
3. The Breeding Goal in Beef.

- The ideal suckler cow must;
  - Calve herself.
  - Calve each year.
  - Have enough milk to rear her calf.
  - Be not too big.
  - Have a good quality calf at foot.
  - In summary, a “balanced” cow.

- She needs to produce more output from less input => more profitable, more sustainable, more carbon efficient.
A balanced cow!
An Irish 5-Star cow.

One of David’s best cows. This nine-year-old SI X cow has a Replacement Index of €169 (5 star, top 1%). She calved for the first time at 24 months, has had eight calves with an average calving interval of 364 days and she weaned the heaviest calf of David’s 2015 calf crop. She is sired by the old Simmental AI bull Hurtig (HRG).
### Euro-Star Replacement Index

<table>
<thead>
<tr>
<th>Trait</th>
<th>Goal</th>
<th>Relative wt</th>
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<tbody>
<tr>
<td>Calving</td>
<td>Less</td>
<td>16%</td>
</tr>
<tr>
<td>Feed Intake</td>
<td>Less</td>
<td>18%</td>
</tr>
<tr>
<td>Carcass wt (for age)</td>
<td>More</td>
<td>21%</td>
</tr>
<tr>
<td>Maternal milk</td>
<td>More</td>
<td>18%</td>
</tr>
<tr>
<td>Female fertility</td>
<td>More</td>
<td>23%</td>
</tr>
<tr>
<td>Docility</td>
<td>More</td>
<td>4%</td>
</tr>
</tbody>
</table>

**Emphasis:**
- **Cow traits 71%**
- **Calf traits 29%**
Does it work? Cow Analysis.

- 162,363 females that were born in 2011 and subsequently entered the suckler herd as female replacements.
  - Across a range of breeds.
- Compared performance of 5 star females (top 20% rank on replacement index), relative to 1 star females (bottom 20% rank on replacement index).
- Are the 5 star females better for the key profit traits?
### Performance of All Suckler Cows Born in 2011 when Ranked on New Genomic Test Proofs

<table>
<thead>
<tr>
<th>Star Rating</th>
<th>No. of Cows</th>
<th>Replacement Index</th>
<th>% Still Alive</th>
<th>Calf Weaning Weight (kg)</th>
<th>Cow Milk Score (1-5)</th>
<th>Age 1st Calving (months)</th>
<th>Calving Interval (days)</th>
<th>No. of Calvings</th>
<th>Carcass Weight (kg)</th>
<th>Carcass Value</th>
<th>Age at Slaughter (days)</th>
</tr>
</thead>
<tbody>
<tr>
<td>★★★★★</td>
<td>33,493</td>
<td>€108</td>
<td>83%</td>
<td>336</td>
<td>4.08</td>
<td>30.2</td>
<td>403</td>
<td>2.69</td>
<td>358</td>
<td>€1,474</td>
<td>697</td>
</tr>
<tr>
<td>★★★★</td>
<td>24,317</td>
<td>€76</td>
<td>80%</td>
<td>324</td>
<td>3.87</td>
<td>30.9</td>
<td>407</td>
<td>2.56</td>
<td>356</td>
<td>€1,469</td>
<td>712</td>
</tr>
<tr>
<td>★★★</td>
<td>21,644</td>
<td>€60</td>
<td>79%</td>
<td>319</td>
<td>3.74</td>
<td>31.3</td>
<td>411</td>
<td>2.47</td>
<td>356</td>
<td>€1,470</td>
<td>715</td>
</tr>
<tr>
<td>★★</td>
<td>20,908</td>
<td>€43</td>
<td>76%</td>
<td>315</td>
<td>3.61</td>
<td>31.5</td>
<td>416</td>
<td>2.40</td>
<td>357</td>
<td>€1,475</td>
<td>721</td>
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<tr>
<td>★</td>
<td>23,911</td>
<td>€12</td>
<td>72%</td>
<td>309</td>
<td>3.36</td>
<td>32.1</td>
<td>423</td>
<td>2.25</td>
<td>357</td>
<td>€1,477</td>
<td>726</td>
</tr>
</tbody>
</table>

**Difference**

| 5 Star V's 1 Star | +€96  | 11% | 27kg | 0.72 | -1.9 months | -20 days | 0.44 calves | 0kg | €-2 | -29 days |

Performance of all suckler females born in 2011 when ranked on new genomic test proofs.
Does it work? Herd Analysis.

- ICBF Replacement Index.
  - Average replacement index for herd.

- Bord Bia Carbon Navigator.
  - Data collected on a number of herd metrics including; (i) numbers animals by age, (ii) length grazing season, (iii) manure management etc. => Herd Assessment of CO2 emissions produced per Kg beef

- Are herds of higher genetic merit for Replacement Index more carbon efficient?
  - Analysis based on 1550 herds with data.
High Genetic Merit Herds are More Carbon Efficient.

<table>
<thead>
<tr>
<th>Herd Rank</th>
<th>Herd Ave</th>
<th>Change in profit/cow/year</th>
<th>Carbon Emmissions per kg Beef</th>
</tr>
</thead>
<tbody>
<tr>
<td>Top 10%</td>
<td>€109.4</td>
<td></td>
<td>12.44</td>
</tr>
<tr>
<td>2</td>
<td>€94.6</td>
<td>-€29.6</td>
<td>12.68</td>
</tr>
<tr>
<td>3</td>
<td>€88.3</td>
<td>-€42.2</td>
<td>12.62</td>
</tr>
<tr>
<td>4</td>
<td>€83.7</td>
<td>-€51.3</td>
<td>13.09</td>
</tr>
<tr>
<td>Mid 50%</td>
<td>€79.3</td>
<td>-€60.3</td>
<td>12.87</td>
</tr>
<tr>
<td>6</td>
<td>€75.1</td>
<td>-€68.6</td>
<td>13.05</td>
</tr>
<tr>
<td>7</td>
<td>€71.0</td>
<td>-€76.9</td>
<td>13.20</td>
</tr>
<tr>
<td>8</td>
<td>€65.8</td>
<td>-€87.2</td>
<td>13.28</td>
</tr>
<tr>
<td>9</td>
<td>€58.6</td>
<td>-€101.5</td>
<td>13.19</td>
</tr>
<tr>
<td>Btm 10%</td>
<td>€43.1</td>
<td>-€132.5</td>
<td>13.54</td>
</tr>
</tbody>
</table>

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We have all made climate change pledges.
The EU is strongly committed.

EU council conclusions (Climate Change Report, Oct 2014), Paragraph 2.14

- .....to ensure coherence between the EU's food security and climate change objectives.
- .....to examine the best means of encouraging the sustainable intensification of food production, while optimising the sector's contribution to greenhouse gas mitigation......

As a net food exporter, IRE must do more!

John Muldowney, DAFM, 2016
4. Irish Beef Data & Genomics Program
Over 1,000 farmers a day applying for new beef genomics scheme

Over 5,000 farmers have now applied to join the Beef Data and Genomics Programme and applications are coming into the Department at a rate of more than 1,000 per day, according to the Minister for Agriculture, Simon Coveney.

The scheme is a key measure under Ireland’s Rural Development Plan and will see investment of some €300m into suckler farming over the next six years.

Commenting on the applications to date the Minister said it shows that beef farmers have decided that engagement with the scheme represents good business planning.

He said the scheme remains on target for the envisaged participation rate of 35,000 farmers in total for which funding of €52m per year has been provided in Department’s Rural Development Programme.
The Irish BDGP Scheme.

- Focused on breeding more profitable, sustainable and carbon efficient cows.
- Funded from EU Rural Development Program.
  - Co-funded by Irish government (DAFM).
- €300m total funding 6 years (2015-2020)
  - Farmers paid ~€90/cow/year to complete key actions re: the scheme.
  - ~€40m allocated towards cost genotyping. ~500k animals genotyped to-date.
  - ~2.5m animals in total will be genotyped during period of scheme. ~30k/wk at max. Now!
Key Project partners.

- **DAFM/EU**: Scheme “owners” and responsible for scheme delivery.
- **ICBF**: Data collection, genotyping, delivery of genetic/genomic evaluations & reports.
  - Role of Scientific Advisory Committee (Amer, Garrick, Mantysaari, Meuwissen & Veerkamp).
- **Teagasc**: Research, extension & training.
- **Illumina**: Delivery of IDB 54k cust chip.
- **Weatherby’s/Eurofins**: Lab services.
- **Bord Bia**: Carbon Navigator.
Key Actions; Tagging

- Started with tagging cows (for reference population), now moving more toward female calves => potential female replacements.
- Pedigree males also prioritised.
Key Actions; Data Recording

- Farmers receive forms regularly re: data recording (including any animals that are missing data).
- Paper based and electronic recording.
Key Actions; Data recording

Very good h2 estimates for farmer recorded traits, e.g., 0.25 for cow milk score with an rg of 0.8 with maternal weaning weight.
Key Actions; % 4 & 5 star females.

Farmers must have a minimum of 20% of breeding females as 4 or 5 stars by 2018 and 50% by 2020. At least one breeding male must be 4 or 5 star by 2019.
Key Actions; Training.

- All participants have to attend a 4-hour training session. Groups of 25 farmers.
- Undertaken by Teagasc.
- 24k participants will be trained by Nov 2016.
- Big focus on benefits of genetics.
- hugely positive response to training.
- Supporting articles in IFJ.
Key Actions; Carbon Navigator

- On-line assessment of the carbon efficiency of each farm.
  - Key data such as number animals, age, gender, length grazing season, N fertiliser efficiency....
  - To be completed by end year with an advisor.
- Ongoing assessment => benchmark improvements.
## Evolution of ICBF Beef Evaluations.

<table>
<thead>
<tr>
<th>Year</th>
<th>Pedigrees</th>
<th>Calving</th>
<th>Live-weight</th>
<th>Calf Quality</th>
<th>Carcass</th>
<th>Fertility</th>
<th>Foreign EBVs</th>
<th>Genotypes</th>
</tr>
</thead>
<tbody>
<tr>
<td>2005</td>
<td>39 m</td>
<td>10 m</td>
<td>4 m</td>
<td>2 m</td>
<td>7 m</td>
<td>4 m</td>
<td>50 k</td>
<td>530 k</td>
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<tr>
<td>2007</td>
<td></td>
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<td>2010</td>
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<td>2013</td>
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<tr>
<td>2015</td>
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</tbody>
</table>

- Within breed muscle and skeletal for LM, CH, SI (40k)
- Across breed. New calving (200k recs) and carcass evaluations (100k recs)
- New fertility and cow milk-ability evaluations
- First overall beef profit indexes
- 39 million pedigrees
- Calving 10m recs
- Live-weight 4m recs
- Calf Quality 2m recs
- Carcass 7m recs
- Fertility 4m recs
- 50,000 foreign ebvs
- 530,000 genotypes
Range of breeds & cross-breeds.

- 533,093 animals with genotypes.
- 30 different breeds.
- 791 different sire breed * dam breed combinations.
- ~68% of data is from cross-bred animals.
Approach to Genomic Evaluations.

- Two step (SNP BLUP then blending) applied successfully in dairy cattle since 2009.
- Mix99 software used (Luke, Finland).
- Preference to use Single Step (SS) GBLUP.
  - Multiple breeds including cross-breds, cows & calves.
- “Hard” deadline of August 2016 for delivery of “official” genomic evaluations.
- After ~12 months intensive R&D, took a decision in May 2016 to proceed with 2-step, NOT 1-step.
- Farmers needed proofs to make decisions ahead of 2018 and 2020 replacement deadlines.
Experience with ssGBLUP.

- Existing evaluations were developed to utilise all available data.
  - Beef performance evaluation was a 29 trait model with 7m records, to predict 6 goal traits.
  - Models needed to be simplified to incorporate genomics.
- Some traits were not converging as well as others, e.g. cow survival & maternal weaning weight.
- Computer resource quickly became a problem
  - RAM (Random Access Memory) to create H-Inv
  - Hard disk space: huge temporary files
Solutions investigated.

• Short term.
  – Purchase more computer resource.
  – Split evaluation into multiple runs with core group of genotypes in each run.
  – Concentrate on males only initially.

• Long term
  – Use the SAC to investigate longer term options.
    • LUKE: Application of APY method.
    • WUR and Iowa State University: Variations of Single Step Bayesian Regression.
    • NMBU: ssGBLUP by genotype imputation.
Computer requirements for ICBF evaluations

- **iPhone 5**: 1 GB RAM
- **109**: Ram 64GB, Disk 1,800GB
- **143**: Ram 120GB, Disk 40,000GB
- **151**: Ram 760 GB, Disk 4,000 GB
- **163**: Ram 2GB, Disk 698GB
- **2005**: Ram 16GB, Disk 279GB
- **2007**: Ram 6000 GB, Disk 40,000 GB
- **2010**: Ram 356 GB, Disk 4,000 GB
- **2013**: Ram 6,000 GB, Disk 40,000 GB
- **2015**: Ram 6,000 GB, Disk 40,000 GB
Experience with ssGBLUP

- Solution 1: Splitting evaluations into subsets

**Validation females**

No of females 11401 correlation $r = 0.994$

Dataset1 = 0.02 {stdev = 0.08}

Dataset2 = 0.02 {stdev = 0.08}

Correlation of 0.98 for core males but 0.90 for females. Made us nervous!
2-Step Genomic Evaluation

Univariate evaluations
n = 16 goal traits

Deregression

SNP BLUP

IDB Genotypes

Impute to 50k

PA from subset of genotyped ancestors using traditional relationships

Direct Genomic Value

Blending by selection index
(Van Raden et al. 2009)

GEBVs

7 conventional multi-trait evaluations
63 traits

Official from Aug 2016, running ~monthly
Correlation in proofs.

- Correlations fairly consistent across breeds.
- Correlations are lower for some traits, mainly due to simplification of models.
- Using genomics, reliability of evaluations for young animals have doubled from 20% => 40%+

<table>
<thead>
<tr>
<th>Index1</th>
<th>Index2</th>
<th>AA</th>
<th>AU</th>
<th>BA</th>
<th>BB</th>
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<th>HE</th>
<th>LM</th>
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<td>Replacement_Off</td>
<td>Repl_New_Geno</td>
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<td>0.96</td>
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<td>0.99</td>
<td>1.00</td>
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<tr>
<td>Cow Survival_Off</td>
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<td>0.85</td>
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<td>Cow Survival_Off</td>
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<td>0.83</td>
<td>0.86</td>
<td>0.81</td>
<td>0.89</td>
<td>0.77</td>
<td>0.86</td>
<td>0.83</td>
<td>0.88</td>
<td>0.82</td>
</tr>
<tr>
<td>CowSurv_New_Geno</td>
<td>CowSurv_New_NonGeno</td>
<td>0.98</td>
<td>0.96</td>
<td>0.98</td>
<td>0.90</td>
<td>0.90</td>
<td>0.97</td>
<td>0.98</td>
<td>1.00</td>
<td>0.94</td>
<td>0.92</td>
<td>0.96</td>
<td>0.99</td>
<td>0.96</td>
</tr>
</tbody>
</table>
Other Challenges.

- Pedigree errors, especially for herdbook registered animals.
  - ~15% sire-calf errors.
    - Farmers generally happy. With genomics can predict 50%+ of these and increasing.
    - Moving to DNA-based calf registration from next year => Removal of pedigree errors.
- Lab/human errors.
  - Even at 0.5% = 1500 problems to resolve!
Next Steps.

• Now that we are operational, more time for R&D.
  – Continue work toward single step genomic evaluations.
  – Impact of using cross-bred data?
  – Impact of using data from one breed to predict a second breed?
  – Approach to validation?

• Further update at EAAP Belfast 2016!
5. Conclusions.

- Genetic/genomics can contribute positively to profitability and carbon efficiency.
  - High genetic merit herds => €130/cow/yr more profit with 9% less CO2/kg beef produced.
- At present, 2-step methods are best to deliver a stable genomic evaluation service.
  - 1-step methods are better. How soon?!
- Move to simpler models.
  - Let genomics/biology be drivers, not predictors.
- The BDGP has had a huge impact on the uptake/interest in genetics.
Final Thought.

- Climate change is one of the “major” issue for governments.
- Genetic/genomics can play a key part.
- Other benefits will accrue, e.g., identification, ancestry, traceability, genetic gain (for other traits).....international collaboration.
- Develop projects linking genomics with climate. Think “BIG” as the money will be spent elsewhere!
Acknowledgement.

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  – For more information, please see ICBF and DAFM websites.
  – Contact myself acromie@icbf.com.

• All partners involved in the Irish Beef Data and Genomics Project.

• DAFM FIRM/Stimulus for travel support