The potential for the application of genomic selection approaches for small ruminants in developing countries

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67th Annual Meeting of the European Federation of Animal Science

Belfast, UK

29th August – 2nd September, 2016

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ICARDA Science for Better Livelihoods in Dry Areas

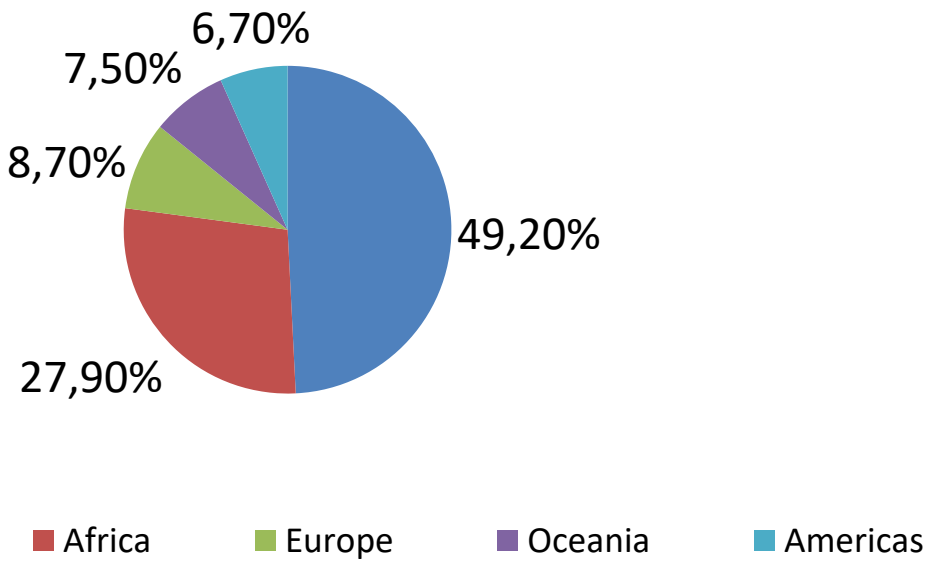
Distribution of Sheep and Goats (FAOSTAT: 1993-2013)

Large genetic diversity and well adapted to diverse production systems and agro-ecologies

A high level of participation by women - empowering women and youth

Provide a wide range of products: milk, meat, skins and hair

Plays critical socio-cultural roles in many communities



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Some African breeds of Goats and Sheep (about 98 and 122 local breeds of goats and sheep in Africa (DAD-IS)

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Genetic improvement lacking in the smallholder systems

Mostly, genetic improvements are lacking in the smallholder system. Major constraints include:

- Lack of performance and pedigree information
- Small flock sizes, therefore difficult to define adequate contemporary groups
- Inadequate of institutional framework and infrastructure to support breeding activities
- Advanced reproductive technologies are difficult to apply

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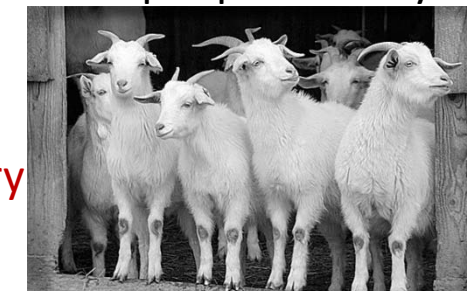
Few examples of genetic improvement in developing countries

Few examples of genetic improvements:

- South Africa: Genetic improvement programs for meat in the Boer goat breed, White Savanna and Kalahari Red goats. Selection based mainly on the conventional hand and eye method. Angora goat for mohair production both conventional and genetic methods
  - Subjectivity in the phenotyping and selection process result in inconsistencies in production as best animals are not always selected
- Genetic improvement for growth and disease resistance in Dorper/Red Massai crosses at Kapiti farm, Kenya. Source of breeding rams to surrounding farms
- Community based breeding programs in several breeds of sheep in Ethiopia involving 2000 households 23 villages with more than 12000 people directly benefiting from the schemes
- Several cross-breeding improvement programs: Meru Dairy Goat Breeder Association (since 1996) and Dairy Association of Kenya (since 1992)



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Unique role of indigenous breeds of small ruminants

Indigenous breeds of goats and sheep in the smallholder systems

are a unique set genotypes:

- They are adapted to surviving under harsh conditions and are disease/parasite resistance. Well adapted to specific agro-ecological zones. Few examples:
  - Kaffa goats, Djalonke Sheep and West Africa dwarf goats are trypanotolerant
  - Red Massai – resistance to internal parasites
  - Abergelle goat is drought tolerance

- Consequently most of the initial molecular genetics research has been focused in understanding and harnessing these unique features

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Past and on-going molecular genetics research on small ruminants in Africa

Much of molecular genetics research on small ruminants in Africa has been through Beca-ILRI HuB, ICARDA and AGIN

- Harnessing genetic diversity for improving goat productivity in Africa
  - Exploration of the goat and sheep genetic landscape
    - Phenotypic and morphological analyses
    - Laboratory based genetic diversity studies using molecular markers
    - Development of additional molecular markers and linkage of specific markers, genes or QTLs to performance and other traits
    - Analysis to identify signatures of selection mostly for adaptation

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Past and on-going molecular genetics research on small ruminants in Africa

- BecA projects in Ethiopia and Cameron have identified regions (KISS1 gene polymorphism) associated the with twining
- Elbeltagy et al (2016) identified regions related to stress grazing in hot and dry arid conditions in Egyptian Sheep and Goat using GWAS

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Trajectories for the small ruminant sector and opportunities for genomics selection

Breeds with some degree of genetic improvement and infrastructure : One end of the spectrum are breed with some organisation structures (breed societies) in place. Some investment in IT, infrastructure and production is under on commercial scale. Examples Boer, Savanna , Kalahari and Angora goat breeds in South Africa. **Productivity traits –**Adaptive traits

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Genomic selection in breeds with conventional improvement schemes

Breeds with some degree of genetic improvement and

infrastructure : (**Productivity traits** - Adaptive traits)

- Classical Genomic selection could be applied (GBLUP or single step)
- Performance data can now be captured using of digital systems
  - No huge organizational infrastructure and high costs of usual of recording systems.
  - Currently in use for collecting sheep performance data several sites in Kenya
- Additional benefits include:
  - Reduces the need for accurate pedigree recording as genomic relationship can easily be computed
  - Parentage discovery using SNP data
  - Ability to control the rate of inbreeding computed from SNP data.

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Trajectories for the small ruminant sector and opportunities for genomics selection

Smallholder Systems: Mostly many smallholders keeping small ruminants in low-productive systems with little or no infrastructure. About 63 to 85% of the small ruminants are raised in this environment . However the need for transition to raising more productive animals in more efficient, intensive and market-linked systems is recognised. **Productivity traits - Adaptive traits.**

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Genomic selection in smallholder systems

Smallholder systems : (**Productive traits – Adaptive traits**)

- Innovative Genomic selection (GS) will be needed
- Current GS in small ruminants are most on productive traits put adaptive traits play a very important role
- Community based breeding program (CBBP) seems to be one of the best approaches for implementing GS:
  - CBBP circumvents most of the previous bottlenecks to genetic improvement system
  - Community based breeding programs in several breeds of sheep in Ethiopia involving 2000 households 23 villages with more than 12000 people directly benefiting from the schemes
  - Recording performance data is implemented by digital means
  - Objectives goals are designed with farmers participation and account for the production environments

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Incorporating important genome regions

Benefits of the CBBP continues :

- Rotational use of selected males
- Within breed selection ensuring adaptability of local breeds can be monitored
- Mimicking the dairy cattle situation, all males could be genotyped with young males genotyped only with a low density chip followed by imputation
- Several scenarios need to be evaluated taking into account the economics aspects
- Mating can be designed to control the rate on inbreeding

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Unique role of indigenous breeds of small ruminants

- Production and adaptive traits can be optimized in the context of CBBP via gene/genome/haplotype block editing utilizing the genomic regions identified in combination with genomic selection in developing appropriate synthetic breeds

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Trajectories for the small ruminant sector and opportunities for genomics selection

Fragile growth systems - (mostly the pastoralists): Here rapid, market-focused growth is not usually the main goal as it is associated with high risks. Productivity is severely limited by *remoteness, harsh climates or environments*, or by poor institutions, infrastructure and market access. Main emphasis is to enhance the important roles of livestock in the resilience of people and communities to environmental variability.

Productivity traits - Adaptive traits.

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Genomic selection in smallholder systems

Fragile growth systems : (Productive traits – **Adaptive traits**)

- Adaptive traits are key and may the goal is to maximize adaptive diversity. Innovative genomic selection will be needed
- Even digital data recording will be a challenge and will require adequate farmer training
- GWAS and positive signatures of selection to identify regions of genome associated with various aspects adaptation (disease and drought for instance)
- Genomic data gives for better understanding of genetic diversity in the fragile growth sector and how to select for it: For instance
  - Uses weighted G to optimize various aspects of adaptation
  - Usage of gene editing in addition to genomic selection to increase and optimize frequency of alleles for different aspects of adaptation (Jenko et al, 2015)

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Application of genomic selection at a national or regional level: Million Bucks initiative

Researchers and academics – develop and provide breeding technologies

Nucleus breeding for superior bucks at hubs – also may breed forages

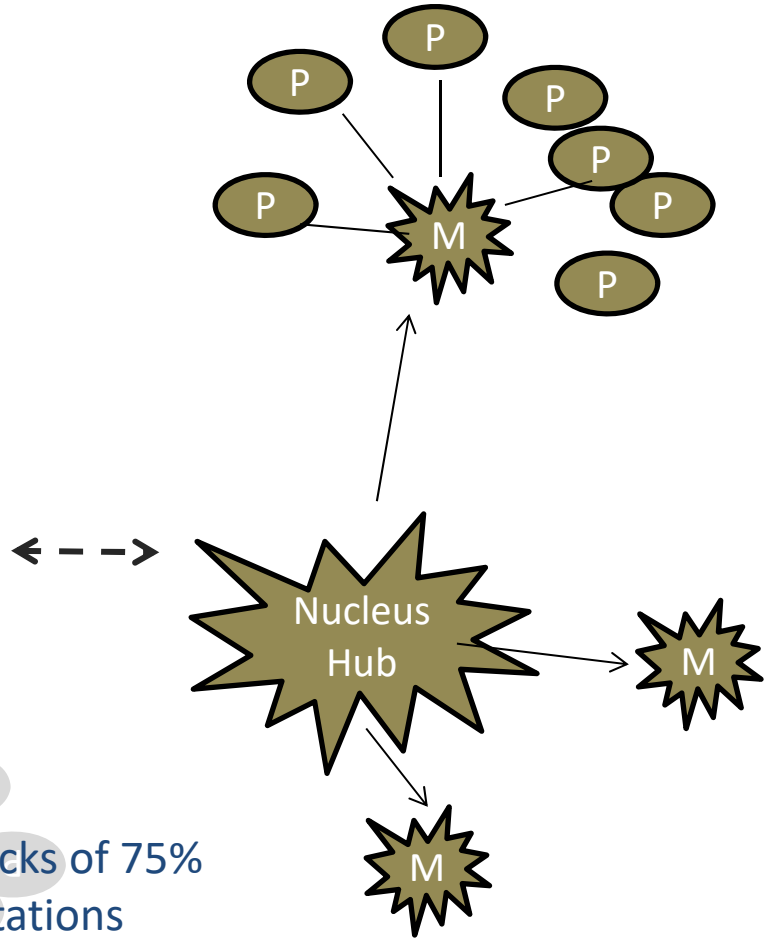
Stock multiplication at intermediate farms embedded within rural communities – market access and services

Small-Medium goat producers (cull inferior stock and grow stock for the market).

Currently a similar structure is the basis:

Meru Dairy Goat Breed Association Kenya offering bucks of 75% exotic breed (Toggenburg) for usage in several buck stations

Dairy Goat Association of Kenya: 75% exotic breed (Alpine), 16K membership; lease a buck for about 40 USD



Application of genomic selection at a national or regional level: Million buck initiative

Advantages of such system for genomics:

- More accurate phenotyping and possibilities of innovative phenotyping
- Rapid rate of genetic progress possible
- Better disease control
- Large scale operation, so could more cost efficient
- Very suitable for the cross breeding set up

Some Issues (especially within breed selection for local breeds):

- To ensure adaptation to different agro-ecological zone, separate breeds/lines may have been maintained if implemented at national level
- Ensure Smallholders have input in designing breeding objectives to own the final product
- May not be suitable for the fragile growth sector where diverse adaptability is key

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Economic sustainability

Implementing of genomic selection especially in low-input

systems should be accompanied by a cost-benefit analysis

- Shumbusho et al (2016)- pure GS versus classic selection was not more beneficial in a French meat sheep breed except some early measured phenotypes are included
- Marketing issues that may accompanied improved productivity must be adequately assessed
- Prevailing socio—economic status of farmers, flock structures and dynamics within smallholding must be understood
- Cost be reduced by sharing facilities already in existence for other livestock species such as cattle

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Conclusions

- Genomics selection in small ruminants in developing countries will not be one-size fits all
- Classic GS is feasible in breeds with some degree of conventional genetic improvement already in place
- The CBBP provides a good framework for the implementation of GS in small holder system.
- Innovative GS will be needed in fragile growth systems where adaptability is main key. Identifying regions of genome associated with various aspects of adaptability and maximizing diversity of adaptability in animals reared will be essential

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Conclusions

- Unique genotypes of several goat and sheep breeds in Africa present good opportunity for understanding genetic diversity and adaptation. The use of gene/haplotype editing and other breeding strategies could play a role in incorporating these into breeding programs for increased productivity
- Large nucleus hubs linked to multipliers and then small to medium producers is could be examined as another approach to implementing GS at a national or regional level but will require more investment
- Adequate cost-benefit analysis should be part of any strategy adopted in implementing GS in these production systems

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Acknowledgements

BecA-ILRI HUB for sponsoring attendance of the conference

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