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Editorial

The Thirteenth Regular Session of the Commission on Genetic Resources for Food and Agriculture took place in Rome in July 2011[1]. The Commission approved the launch of the first call for project proposals under the Funding Strategy for the Implementation of the *Global Plan of Action for Animal Genetic Resources*.[2] The call was published on the Funding Strategy web page[3] in September 2011. The Commission agreed to limit the initial maximum allocation per project to US$50 000 for single-country projects and US$100 000 for bilateral, regional or multilateral projects and to limit the length of projects to not more than two years.

The Commission reviewed progress made to date in the implementation of the *Global Plan of Action*. In line with the reporting schedule agreed at its previous session, the Commission had available to it a report of FAO's activities[4] in support of the implementation of the *Global Plan of Action* and a report on the activities of international organizations[5]. The Commission welcomed the progress made and emphasized the importance of future collaboration between FAO and other organizations including breeding industry organizations. It also invited FAO to work further on the development of targets and indicators to evaluate progress in the implementation of the *Global Plan of Action*. The next phase in the reporting schedule will be the preparation country reports on implementation activities at national level. In January 2012, countries will be requested by FAO to complete an electronic questionnaire based on the template agreed upon by the Commission at its previous session. The Commission also stressed the need for countries to update their breed-related data in the Domestic Animal Diversity Information System (DAD-IS). A new status and trends report on animal genetic resources will be produced by FAO in time for the meeting of the Intergovernmental Technical Working Group on Animal Genetic Resources, currently planned for October 2012, and more comprehensive and up-to-date breed population figures are urgently required if global trends are to be monitored adequately.

The Commission endorsed five guideline publications prepared by FAO to support countries in their implementation of the *Global Plan of Action*. Guidelines on *Developing the institutional framework for the management of animal genetic resources*[6] and *Surveying and monitoring of animal genetic resources*[7] are in press, and guidelines on *Phenotypic characterization of animal genetic resources*, *Molecular genetic characterization of animal genetic resources*, and *Cryoconservation of animal genetic resources* are forthcoming in 2012.

This was also the Commission's first meeting since the adoption of the Nagoya Protocol on Access and Benefit Sharing. The Commission noted with appreciation the recognition that the Protocol gives to the importance and special nature of genetic resources for food and agriculture. It invited countries to take these factors into account when addressing access and benefit sharing. It decided to establish an Ad Hoc Technical Working Group on Access and Benefit-sharing for Genetic Resources for Food and Agriculture. The Commission invited FAO to assist countries to initiate the development of policies and protocols for the exchange of animal genetics resources for the purpose of multicountry activities, including gene banking, and requested its Intergovernmental Technical Working Group on Animal Genetic Resources to discuss measures to facilitate international exchange of genetic material. The Commission invited countries to consider, in the development and implementation of national access and benefit sharing arrangements, the importance and specific characteristics of animal genetic resources and their role in food security.

Another important recent development has been the establishment of the Sub-Regional Focal Point for Animal Genetic Resources in West and Central Africa, which adds to the existing Regional Focal Points in Europe and in Latin America and the Caribbean. The Commission called for further effort to establish or re-establish focal points in other regions and subregions.

The Commission Meeting was preceded by a special information seminar on climate change and genetic resources for food and agriculture. A Background Study Paper on *Climate change and animal genetic resources: state of knowledge, risks and opportunities*[8] was presented at the seminar, along with similar papers on other subsectors of genetic resources. Awareness of the significance of climate change for the management of genetic resources was evident throughout the week's discussions. The Commission specifically requested that FAO, in its training and capacity building activities, ensure that emphasis is given to the threat posed by climate change and to the roles of well-adapted species such as camels.

[1] see report at: http://www.fao.org/docrep/meeting/023/mc192e.pdf
[2] http://www.fao.org/docrep/012/i1674e/i1674e00.htm
[3] http://www.fao.org/ag/againfo/programmes/en/genetics/Funding_strategy.html
[4] http://www.fao.org/docrep/meeting/022/mb180e.pdf
[5] http://www.fao.org/docrep/meeting/022/am648e.pdf
[6] http://www.fao.org/docrep/014/ba0054e/ba0054e00.pdf
[7] http://www.fao.org/docrep/014/ba0055e/ba0055e00.pdf
[8] http://www.fao.org/docrep/meeting/022/mb386e.pdf

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Editorial

La treizième session ordinaire de la Commission des ressources génétiques pour l'alimentation et l'agriculture s'est tenue à Rome au mois de juillet 2011.[1] La Commission a approuvé la publication du premier appel à propositions de projets au titre de la Stratégie de financement de la mise en application du *Plan d'action mondial pour les ressources zoogénétiques*.[2] L'appel a été publié sur la page Web de la Stratégie de financement[3] en Septembre 2011. La Commission a convenu de limiter l'allocation initiale par projet à 50 000 dollars EU au maximum pour les projets dans un seul pays et à 100 000 dollars EU pour les projets bilatéraux, régionaux ou multilatéraux, et de fixer la durée d'exécution des projets à deux ans au plus.

La Commission a analysé les progrès réalisés à cette date quant à la mise en œuvre du *Plan d'action mondial.* Conformément au calendrier des rapports, convenu lors de la session précédente, la Commission disposait d'un rapport des activités de la FAO[4] en faveur de la mise en œuvre du *Plan d'action mondial* et d'un rapport des activités des organisations internationales.[5] La Commission a accueilli favorablement les progrès réalisés et a souligné l'importance de la collaboration future entre la FAO et les autres organisations, notamment les organisations du secteur de la sélection animale. Elle a également invité la FAO à persévérer dans l'élaboration d'objectifs et d'indicateurs à utiliser pour l'évaluation des progrès réalisés dans la mise en œuvre du *Plan d'action mondial.* La prochaine phase du calendrier des rapports sera représentée par la préparation des rapports de pays sur les activités de mise en œuvre au niveau national. Au mois de janvier 2012, la FAO demandera aux pays de remplir un questionnaire électronique sur la base du modèle convenu par la Commission lors de la session précédente. La Commission a également souligné la nécessité pour les pays de mettre à jour les données sur les races qui figurent dans le Système d'information sur la diversité des animaux domestiques (DAD-IS). La FAO rédigera un nouveau rapport sur la situation et les évolutions des ressources zoogénétiques pour la réunion du Groupe de travail technique intergouvernemental sur les ressources zoogénétiques pour l'alimentation et l'agriculture, actuellement planifiée pour le mois d'octobre 2012. Il est nécessaire et urgent de disposer de données plus complètes et à jour sur les populations des différentes races si l'on veut suivre de façon adéquate les évolutions mondiales.

La Commission a approuvé la publication de cinq directives élaborées par la FAO pour aider les pays dans la mise en œuvre du *Plan d'action mondial.* Les directives relatives à *La mise en place du cadre institutionnel pour la gestion des ressources zoogénétiques*[6] et à *L'enquête sur et le suivi des ressources zoogénétiques*[7] sont à paraître, et celles qui sont relatives à *La caractérisation phénotypique des ressources zoogénétiques*, à *La caractérisation génétique moléculaire des ressources zoogénétiques* et à *La cryoconservation des ressources zoogénétiques* seront disponibles en 2012.

Il s'agissait également de la première réunion de la Commission depuis l'adoption du Protocole de Nagoya sur l'accès aux ressources génétiques et le partage des avantages découlant de leur utilisation. La Commission a constaté avec satisfaction la reconnaissance que le Protocole attribue à l'importance et à la nature particulière des ressources génétiques pour l'alimentation et l'agriculture. Elle a invité les pays à prendre en compte ces éléments lorsqu'ils abordent les questions d'accès et de partage des avantages. Elle a décidé d'établir un Groupe de travail technique ad hoc sur l'accès aux ressources génétiques pour l'alimentation et l'agriculture et le partage des avantages découlant. La Commission a invité la FAO à aider les pays dans l'établissement de politiques et de protocoles pour l'échange des ressources zoogénétiques dans le cadre des activités multinationales, notamment en ce qui concerne les banques de gènes. Elle a demandé à son Groupe de travail technique intergouvernemental sur les ressources zoogénétiques pour l'alimentation et l'agriculture d'examiner les mesures visant à faciliter l'échange international de matériel génétique. La Commission a invité les pays à prendre en considération, lors de l'élaboration et de la mise en œuvre des dispositions nationales relatives à l'accès et au partage des avantages, l'importance et les caractéristiques spécifiques des ressources zoogénétiques et de leur fonction dans le cadre de la sécurité alimentaire.

L'établissement du Point focal sous-régional pour les ressources zoogénétiques en Afrique de l'Ouest et du Centre, qui s'ajoute aux points focaux en Europe et dans la région Amérique latine et Caraïbes, représente un autre développement récent de grande importance. La Commission a demandé de déployer des efforts supplémentaires pour établir ou rétablir des points focaux dans d'autres régions et sous-régions.

Un séminaire spécial d'information sur le changement climatique et les ressources génétiques pour l'alimentation et l'agriculture a précédé la réunion de la Commission. Une

[1] Voir le rapport à l'adresse électronique: http://www.fao.org/nr/cgrfa/cgrfa-meetings/cgrfa-comm/thirteenth-reg/en/
[2] http://www.fao.org/docrep/012/i1674f/i1674f00.htm
[3] http://www.fao.org/ag/againfo/programmes/fr/genetics/Funding_strategy.html
[4] http://www.fao.org/docrep/meeting/022/mb180f.pdf
[5] http://www.fao.org/docrep/meeting/022/am648e.pdf
[6] http://www.fao.org/docrep/014/ba0054e/ba0054e00.pdf
[7] http://www.fao.org/docrep/014/ba0055e/ba0055e00.pdf

étude de référence intitulée *Climate change and animal genetic resources: state of knowledge, risks and opportunities*[8] (Changement climatique et ressources zoogénétiques: état des connaissances, risques et opportunités) a été présentée au séminaire, ainsi que des documents similaires relatifs à d'autres sous-secteurs des ressources génétiques. La prise de conscience de l'importance du changement climatique pour la gestion des ressources génétiques a été manifeste dans tous les débats de la semaine. La Commission a demandé spécifiquement à la FAO d'insister, dans le cadre de ses activités de formation et de renforcement des capacités, sur l'importance de la menace représentée par le changement climatique et sur l'intérêt des fonctions des espèces bien adaptées, comme les chameaux.

[8] http://www.fao.org/docrep/meeting/022/mb386e.pdf

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Editorial

En julio de 2011, tuvo lugar en Roma la Decimotercera Sesión Ordinaria de la Comisión de Recursos Genéticos para la Agricultura y la Alimentación.[1] La Comisión aprobó el lanzamiento de la primera convocatoria de propuestas de proyectos que forma parte de la Estrategia de financiación para la implementación del *Plan de Acción Mundial sobre los Recursos Zoogenéticos*.[2] La convocatoria fue publicada en la página web de la Estrategia de financiación[3] en septiembre de 2011. La Comisión acordó limitar la asignación máxima inicial por proyecto en 50 000 dólares estadounidenses para proyectos nacionales individuales y en 100 000 dólares estadounidenses para proyectos bilaterales, regionales o multilaterales, y limitar la duración de los mismos a un periodo no superior a dos años.

La Comisión examinó el avance que se ha producido hasta la fecha en relación a la implementación del *Plan de Acción Mundial*. Con arreglo al calendario de presentación de informes acordado en su reunión anterior, la Comisión facilitó un informe de las actividades de la FAO[4] para apoyar la implementación del *Plan de acción mundial*, así como un informe sobre las actividades de las organizaciones internacionales[5]. La Comisión se mostró muy satisfecha con los avances conseguidos y destacó la importancia, de cara al futuro, de la colaboración entre la FAO y otras organizaciones, incluyendo organizaciones relacionadas con la industria de la mejora genética. Asimismo, invitó a la FAO a seguir trabajando en el desarrollo de metas e indicadores para evaluar el nivel de progreso alcanzado en la implementación del *Plan de Acción Mundial.* La siguiente fase en el calendario de presentación de información será la elaboración de informes nacionales sobre la implementación de actividades a nivel de país. En enero de 2012, la FAO solicitará a los países que completen un cuestionario electrónico basado en una plantilla acordada por la Comisión en su sesión anterior. De igual modo, la Comisión subrayó la necesidad de que los países actualicen la información relativa a sus razas, contenida en el Sistema de Información de la Diversidad de los Animales Domésticos (DAD-IS, por sus siglas en inglés). La FAO, con suficiente antelación, elaborará un nuevo informe sobre la situación y las tendencias de los recursos zoogenéticos para la reunión del Grupo de Trabajo Técnico Intergubernamental sobre los Recursos Zoogenéticos, actualmente prevista para octubre de 2012, existiendo la necesidad de que se completen y actualicen con premura las cifras, si se pretende supervisar de forma adecuada la tendencia mundial.

La Comisión aprobó la publicación de cinco líneas directrices preparadas por la FAO, para apoyar la implementación por parte de los países del *Plan de Acción Mundial*. Las líneas directrices sobre la *Elaboración del marco institucional para la gestión de los recursos genéticos*[6] y la *Realización de encuestas sobre y el seguimiento de los recursos genéticos*[7] están en fase de impresión, y las líneas directrices sobre la *Caracterización fenotípica de los recursos zoogenéticos*, la *Caracterización genética molecular de los recursos zoogenéticos* y la *Crioconservación de los recursos zoogenéticos* están pendiente de publicarse para 2012.

Ésta ha sido también la primera reunión de la Comisión desde la adopción del Protocolo de Nagoya sobre el Acceso y la participación en los beneficios. La Comisión destacó el reconocimiento que el Protocolo hace a la importancia y a la especial naturaleza de los recursos genéticos para la alimentación y la agricultura. Se ha invitado a los países a tener en cuenta estos factores cuando se traten aspectos relacionados con el acceso y la participación en los beneficios. Se decidió establecer, especialmente para este fin, un Grupo especial de trabajo técnico sobre el acceso y la distribución de beneficios en relación con los recursos genéticos para la alimentación y la agricultura. La Comisión invitó a la FAO a ayudar a los países a comenzar a trabajar en el desarrollo de políticas y protocolos para el intercambio de recursos genéticos, con el propósito de poner en marcha actividades entre varios países, que incluyeran los bancos de germoplasma, y solicitó a su Grupo de Trabajo Técnico Intergubernamental sobre los Recursos Zoogenéticos a tratar las medidas para facilitar el intercambio internacional de material genético. La Comisión invitó a los países a considerar la importancia y las características específicas de los recursos zoogenéticos y su papel en la seguridad alimentaria, en el desarrollo e implementación de acuerdos relativos al acceso nacional y la participación en los beneficios.

Otro avance importante, acontecido recientemente, ha sido la creación del Punto Focal Sub-regional para los Recursos Zoogenéticos en África Central y del Oeste, que se suma a los Puntos Focales Regionales existentes en Europa y en América Latina y el Caribe. La Comisión pidió que se llevase a cabo un esfuerzo mayor para el establecimiento o restablecimiento de puntos focales en otras regiones y subregiones.

[1] véase informe: http://www.fao.org/nr/cgrfa/cgrfa-meetings/cgrfa-comm/thirteenth-reg/en/
[2] http://www.fao.org/docrep/012/i1674s/i1674s00.htm
[3] http://www.fao.org/ag/againfo/programmes/es/genetics/Funding_strategy.html
[4] http://www.fao.org/docrep/meeting/022/mb180s.pdf
[5] http://www.fao.org/docrep/meeting/022/am648e.pdf
[6] http://www.fao.org/docrep/014/ba0054e/ba0054e00.pdf
[7] http://www.fao.org/docrep/014/ba0055e/ba0055e00.pdf

La reunión de la Comisión estuvo precedida por un seminario sobre el cambio climático y los recursos genéticos para la alimentación y la agricultura. Se presentó un documento sobre un estudio relativo al *Cambio climático y los recursos zoogenéticos: grado de conocimiento, riesgos y oportunidades*[8], junto a trabajos similares en otros subsectores de los recursos genéticos. Quedó patente, a lo largo de las discusiones mantenidas durante la semana, la conciencia que existe acerca de la importancia del cambio climático para la gestión de los recursos genéticos. La Comisión solicitó de manera expresa a la FAO que, en sus actividades de capacitación y creación de capacidad, se asegurase que se daba la suficiente importancia a la amenaza del cambio climático y al papel desarrollado por especies bien adaptadas, como los camellos.

[8] http://www.fao.org/docrep/meeting/022/mb386e.pdf

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Caracterisation Phenotypique de la Population Ovine du Sud Ouest de la Tunisie

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Résumé
Le présent travail s'est intéressé à la caractérisation de la variabilité phénotypique de la population ovine distribuée dans la région du Sud Ouest de la Tunisie. L'étude a porté sur l'analyse conjointe des caractères quantitatifs et qualitatifs de 987 animaux de trois races ovines dont deux races locales (Barbarine (BAR) et Queue Fine de l'Ouest (QFG et QFT)) et une race exotique d'origine marocaine (D'man (DMN)).

Les résultats des caractères quantitatifs (hauteur au garrot (HG), longueur du corps (LC), périmètre thoracique (PT), poids des mâles (P♂) et poids des femelles (P♀)) ont montré une supériorité significative de la race Queue Fine par rapport aux deux autres races. Pour les caractères qualitatifs, les résultats ont montré qu'au niveau de la couleur de la robe, corne et pendeloques des races Barbarine et Queue Fine de l'Ouest, la couleur blanche est dominante alors que chez la race D'man les couleurs sont variées. Généralement, les femelles des trois races sont mottes. Seuls les mâles de race Queue Fine de l'Ouest sont cornus. La race Barbarine se distingue des autres races par l'absence totale de pendeloques. Chez les deux autres races, l'absence de pendeloques est le caractère dominant.

Les distances génétiques calculées sur la base de ces caractères quantitatifs montrent que les distances trouvées entre les couples Barbarine–D'man et Queue Fine de l'Ouest-D'man sont supérieures à celles trouvées entre les couples Barbarine-Queue Fine de l'Ouest.

Mots-clés: *Tunisie, ovin, morphologie, caractères quantitatifs, caractères qualitatifs, distance génétique*

Summary
The objective of this study was the morphological characterization of the sheep population in the southwest of Tunisia. A joint analysis of quantitative and qualitative characters was carried out on 987 animals of three breeds: two local breeds (Barbarine (BAR) and Queue Fine de l'Ouest (QFG and QFT)) and an exotic breed introduced from Morocco, the D'man (DMN) breed.

Results on quantitative characters (height at withers (HG), body length (LC), thorax perimeter (PT), body weight of males (P♂) and body weight of females (P♀)) showed a significant superiority of the Queue Fine de l'Ouest breed compared to the other two breeds. On the other hand, results on qualitative characters (fleece color, horn and wattles) showed white to be the dominant color of the fleece in the Barbarine and Queue Fine breeds, while for the D'man breed there were various colors. Generally, females of the three breeds were polled while males were horned for the Queue Fine and polled for the Barbarine and D'man breeds. The Barbarine distinguishes itself from the other breeds by the total absence of wattles which are predominantly missing in the other two breeds.

Genetic distances estimated on the basis of quantitative characters showed that distances found between the Barbarine-D'man and Fine Tail of Ouest-D'man breeds were higher than those found between the Barbarine-Queue Fine breeds.

Keywords: *Tunisia, sheep, morphology, quantitative characters, qualitative characters, genetic distance*

Resumen
El objetivo de este estudio fue la caracterización morfológica de la población ovina del suroeste de Túnez. Se llevó a cabo un análisis conjunto de los caracteres cuantitativos y cualitativos sobre un total de 987 animales de tres razas: dos razas locales (la *Barbarine* (BAR) y la *Queue Fine de l'Ouest* (GFC y QFT)) y una raza foránea introducida desde Marruecos, la *D'man* (DMN). Los resultados del estudio de los caracteres cuantitativos (altura a la cruz (HG), diámetro longitudinal (LC), perímetro torácico (PT), el peso corporal de los machos (P ♂) y el peso corporal de las hembras (P ♀)) mostraron una superioridad significativa de la raza *Queue Fine de l'Ouest*, en comparación con las otras dos razas. Por otro lado, los resultados del estudio de los caracteres cualitativos (color de la capa, del cuerno y de las barbas) mostraron una predominancia del color blanco en la capa en las razas *Barbarine* y en la *Queue Fine*, mientras que la *D'man* presentaron varios colores. En general, las hembras de las tres razas eran acornes, mientras que los machos de las razas

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Queue Fine poseían cuernos y los de las razas *Barbarine* y *D'man* eran acornes. La *Barbarine* se distingue de las otras razas por la ausencia total de barbas, que predominantemente no están presentes en las otras dos razas. Las distancias genéticas estimadas sobre la base de los caracteres cuantitativos mostraron que las distancias halladas entre las razas *Barbarine* y *D'man* y las razas *Queue Fine de l'Ouest* y *D'man* eran superiores que las encontradas entre las razas *Barbarine* y *Queue Fine*.

Palabras clave: *Túnez, oveja, morfología, caracteres cuantitativos, caracteres cualitativos, distancia genética*

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Introduction

La première phase de la caractérisation des ressources génétiques locales est l'identification des populations en se basant sur des descripteurs morphologiques et des descripteurs de la distribution géographique. Ces descripteurs permettent la connaissance de la variabilité des caractères morphologiques (Delagado *et al*., 2001). La caractérisation morphologique a été suggérée et utilisée pour décrire et classifier des populations sauvages (Brehem *et al*., 2001) ainsi que les populations des animaux domestiques et d'élevage (Nsoso *et al*., 2004; Zaitoun *et al*., 2005; Traoré *et al*., 2008).

Des travaux scientifiques ont été menés en Tunisie pour étudier, identifier et caractériser la population des animaux domestiques sur le plan morphologique. Une étude menée par Bedhiaf *et al*., (2008) s'est intéressée à l'identification des différents écotypes de la race Barbarine. Les principaux résultats de cette étude ont permis de mettre en évidence au sein de cette race 10 écotypes différents. Avant cette étude, deux écotypes seulement ont été décrits au sein de la race Barbarine, l'un à tête rousse et l'autre à tête noire (Khaldi, 1989; Djemali *et al*., 1994). La population caprine locale du Sud Ouest de la Tunisie a été également décrite en se référant à des caractères morphologiques, ce qui a permis de subdiviser cette population en 4 sous populations (Nafti *et al*., 2009). Le poney des Mogods a été aussi caractérisé en se basant sur des caractères morphologiques (Chabchoub *et al*., 2000; Sebbag, 2002). L'effectif des ovins dépasse les sept millions de tête avec plus que 4 millions d'unités femelles (OEP, 2008). Il existe cependant plusieurs races, élevées dans différentes zones écologiques et conduites selon des systèmes de production spécifiques à chaque zone. La première race et la plus importante (2555600 têtes) (OEP, 2008) est la race Barbarine, connue localement sous le non «Nejdi» ou «brebis à queue grasse». Il s'agit d'une race à grosse queue originaire des steppes asiatiques, introduite en Tunisie par les phéniciens au 4ème siècle avant Jésus-Christ. C'est la race la plus répandue sur le territoire tunisien et elle est exploitée essentiellement pour la production de viande selon un mode d'élevage extensif (Djemali *et al*., 1994). La deuxième race est la race Queue fine de l'Ouest connue aussi sous le nom «Bergui». Son effectif a subit une augmentation durant les 10 dernières années pour atteindre 1264500 têtes (OEP, 2008). C'est une race mixte à lait et à viande et conduite selon un mode de conduite extensif. C'est une race d'origine Algérienne et actuellement cette race occupe les régions ouest de la Tunisie (Snoussi, 2003). Finalement, une nouvelle race exotique à viande a été introduite en 1994 du Maroc dans les oasis tunisienne. Cette race nommée D'man, réputée par ses performances de reproduction exceptionnelles, a connu une large extension, particulièrement dans le milieu oasien au sud du pays. Son effectif est de quelques milliers (OEP, 2008).

L'objectif de ce travail est la caractérisation morphologique, par le biais de cinq caractères quantitatifs et quatre caractères qualitatifs, des trois races ovines exploitées dans le Sud Ouest de la Tunisie.

Matériel et Méthodes

Animaux et échantillonnage

Notre étude a été menée sur un effectif total de 987 animaux de trois races ovines élevés dans deux gouvernorats du sud ouest de la Tunisie (Tableau 1). Les races Barbarine (BAR) et Queue Fine de l'ouest (QFG) dans la région de Gafsa et les races D'man (DMN) et Queue Fine de l'Ouest (QFT) dans la région de Tozeur. Les troupeaux ayant au moins une dizaine de têtes ont été retenus en priorité. D'une manière générale, le sondage a porté sur des mâles et des femelles âgés de plus de deux ans.

Variables mesurées

Les variables et les caractères utilisés pour caractériser phénotypiquement les ovins sont ceux recommandés par la FAO selon le programme DAD-IS (système d'information sur la diversité des animaux domestiques) (FAO, 2000). Le profilage morphologique a été établi à

Tableau 1. Répartition des animaux échantillonnés.

Race	Nombre total	Brebis	Béliers
Barbarine	224	180	44
Queue Fine (Gafsa)	205	150	55
Queue Fine (Tozeur)	205	141	64
D'man	353	310	43
Total	**987**	**781**	**206**

Tableau 2. Variables quantitatives et qualitatives étudiées.

Variable	Abréviation
Hauteur au garrot	HG
Longueur du corps	LC
Périmètre thoracique	PT
Poids des mâles	P♂
Poids des femelles	P♀
Couleur	Cou
Tache	Tache
Cornes	Corne
Pendeloques	Pendeloques

Tableau 3. Fréquences de la couleur de la robe.

Couleur	BAR	QFG	QFT	DMN	Totale
Blanche	0	59,6	93,75	0	45,19
Noire	0	7,01	1,56	23,25	7,21
Rousse	0	0	1,56	2,32	0,96
Grise	0	0	0	6,97	1,44
Blanche et noir	0	19,29	0	0	5,28
Blanche et rousse	0	14,03	3,12	13,95	7,69
Blanche + tête noir	0	0	0	6,97	1,44
Blanche + tête rousse	0	0	0	30,23	6,25
Blanche + tête et membre noir	100	0	0	9,3	23,07

partir de certains caractères quantitatifs et qualitatifs (Tableau 2) choisis parmi ceux qui servent à déterminer les standards des races ovines existantes dans le monde. Les données ont été recueillies à l'aide d'une fiche de sondage qui permet de rassembler toutes les données relatives aux localités enquêtées et à l'identification des différentes variables. Les paramètres quantitatifs ont été mesurés directement sur l'animal. Par ailleurs, certains phénotypes (cornes et pendeloques) ont été enregistrés en termes d'absence/présence.

Analyse statistique

Description morphologique des races ovines

Les statistiques descriptives pour les caractères quantitatifs et les fréquences pour les caractères qualitatifs ont été calculées. Les différences observées au niveau des variables quantitatives ont été aussi étudiées par le modèle linéaire suivant:

$$Y_{ijk} = \mu + Race_i + Sexe_j + Age_k + Sexe\ (Race)_{ij} + \varepsilon_{ijk}$$

Avec y_{ijk} = hauteur au garrot; longueur du corps; périmètre thoracique; ou poids corporel, μ = moyenne générale de la population; $Race_i$ = effet de la $i^{ème}$ race (Barbarine, Queue Fine de l'Ouest Tozeur, Queue Fine de l'Ouest Gafsa, ou D'man); $Sexe_j$ = effet du $j^{ème}$ sexe; Age_k = effet du $K^{ème}$ âge (l= 2, 3 ou 4 ans); $Sexe\ (Race)_{ij}$ = effet du $j^{ème}$ sexe (mâle ou femelle) hiérarchisé dans la $i^{ème}$ race, et ε_{ijk} = erreur résiduelle de moyenne = 0 et de variance constante.

Les analyses décrites ci-dessus ont été faites à l'aide du logiciel SAS (1994). Les moyennes des moindres carrés, au lieu des moyennes brutes, ont été comparées moyennant le test de student «t». La comparaison des moyennes corrigées a pour but de tenir compte des différences d'âge des animaux échantillonnés et de fournir des standards aussi précis que possibles des différentes races surtout les sous populations Queue Fine de l'Ouest Tozeur et Queue Fine de l'Ouest Gafsa.

Distances de Mahalanobis (D2) et dendrogramme

Pour mieux visualiser la différenciation des populations, les distances de Mahalanobis entre les paires de populations ont été calculées (Legendre et Legendre, 1998; Quilichini, *et al*., 2004; Zaitoun *et al*., 2005) en utilisant tous les caractères mesurés. A partir de ces distances, un dendrogramme regroupant l'ensemble des populations a été construit. Le calcul des D2 et la construction du dendrogramme ont été effectués par le programme MVSP (Multi Variate Statistical Package) version 3.1 (Kovach, 2003).

Résultats et discussion

Description des caractères qualitatifs

Les fréquences des couleurs de la robe sont très variables et diversifiées (Tableau 3). Néanmoins, la couleur blanche est la couleur dominante dans les trois races, soit comme couleur unique soit en association avec d'autres couleurs. La race Barbarine a une robe blanche et une tête rousse (Figures 1 et 6). La race Queue Fine de l'Ouest est en majorité blanche avec parfois des taches noires ou rousses sur le corps (Figures 2, 4 et 5), contrairement à la race D'man qui présente une multitude de couleurs et plusieurs combinaisons de couleurs (Figures 3, 7 et 8) avec dominance de la couleur noire suivie de la couleur blanche et noire et enfin la couleur blanche avec tête et membre roux. La dominance de la couleur blanche, seule ou en association avec d'autres couleurs, pourrait être une forme d'adaptation au milieu par le fait du fort ensoleillement et des températures élevées (surtout en été) et aux pratiques d'élevage par le long séjour des animaux sur des parcours étendus ce qui expose les animaux pendant une longue période au soleil (Katongole *et al*., 1994; Traoré *et al*., 2006).

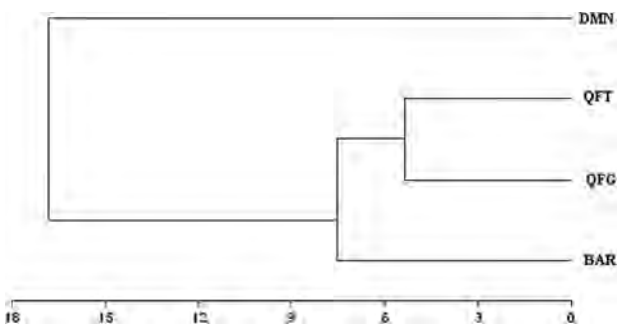

Figure 1. Bélier de race Barbarine.

Figure 2. Bélier de Race Queue Fine de l'Ouest.

Figure 4. Brebis Queue Fine de l'Ouest (Gafsa).

Le Tableau 4 montre qu'en général les femelles des trois races sont mottes, de même pour les mâles des races Barbarine et D'man. La présence de cornes permet de distinguer les mâles de la race Queue Fine de l'Ouest dans les deux régions (Gafsa et Tozeur) par rapport aux D'man et Barbadine. L'absence de cornes est un trait très visible chez la race D'man.

La race Barbarine se distingue des autres races par l'absence totale de pendeloques. Chez les autres races, le caractère «absence de pendeloques» est plus fréquent que le caractère «présence de pendeloques» (Tableau 6). Pour l'ensemble de l'échantillon, les pourcentages d'animaux caractérisés par l'absence de pendeloques est de 72,36 chez les femelles et de 74,02 chez les mâles.

Description des caractères quantitatifs

D'une façon générale, les animaux analysés ont un âge moyen de 4 ans. Les valeurs enregistrées les plus élevées sont celles du périmètre thoracique et de la longueur du corps. Les béliers sont plus lourds que les brebis. Généralement, les populations échantillonnées sont assez hautes sur pattes (Tableau 5).

La variable HG a été hautement influencée ($P < 0,0001$) par la race et le sexe des animaux (Tableau 6). En effet, les animaux de la race Queue Fine de l'Ouest de Gafsa sont les plus hauts sur pattes. Leur hauteur au garrot est supérieure de 2,36 cm, 5,23 cm et 17,06 cm respectivement à celle des races Queue Fine de l'Ouest de Tozeur, la Barbarine et la D'man. Pour toutes les races, les mâles sont toujours plus hauts que les femelles et le facteur sexe affecte de manière hautement significative ($P < 0,0001$) la hauteur au garrot. La différence entres les deux sexes est de 10,96 cm. L'âge n'a démontré aucun effet sur la hauteur au garrot des animaux étudiés.

La race a un effet hautement significatif ($P < 0,0001$) sur le tour de la poitrine. Les ovins Queue Fine de l'Ouest élevés dans la région de Gafsa ont le périmètre thoracique le plus élevé (89,56 cm), suivis des animaux Barbarins et Queue fine de Tozeur. Le caractère tour de la poitrine était comparable pour ces deux derniers échantillons d'animaux Barbarins et Queue fine de Tozeur. Pour l'ensemble des animaux étudiés, le sexe a un effet hautement significatif ($P < 0,0001$) sur le tour de la poitrine (94,39 cm pour les mâles contre 84,01 cm pour les femelles). De même, le facteur âge affecte le tour de la poitrine d'une façon

Figure 3. Bélier de race D'man.

Figure 5. Brebis Queue Fine de l'Ouest (Tozeur).

Figure 6. Brebis de race Barbarine.

Figure 8. Elevage de la race D'man dans les oasis.

significative ($P < 0,05$); les animaux âgés de 3 et 4 ans développent le tour de poitrine le plus grand comparés aux animaux âgés de deux ans.

La longueur du corps des animaux a été mesurée en incluant la longueur de la tête. Tous les facteurs du modèle utilisé montrent une influence hautement significative ($P < 0,0001$) sur ce caractère. Les animaux de la race Queue Fine de Gafsa présentent la longueur du corps la plus élevée par rapport aux autres races; en effet, cette différence est de l'ordre de 2,5 cm par rapport à celle des animaux de la Queue Fine de Tozeur, 2,68 cm par rapport à la moyenne des animaux Barbarins et de 6,84 cm par rapport à la longueur moyenne des animaux de race D'man (Tableau 6).

Le poids corporel comme pour les autres traits, est hautement influencé ($P < 0,0001$) par la race. Il est plus élevé chez la population Queue Fine de l'Ouest élevé dans la région de Gafsa avec une moyenne de 54,46 kg, avec une différence de 10 et 15 kg (Tableau 6) par rapport aux animaux de races Barbarine et D'man respectivement. Le sexe aussi influence de manière hautement significative ($P < 0,0001$) le poids corporel, avec une supériorité nette pour les béliers par rapport aux brebis. Les animaux âgés de 3 et 4 ans sont toujours plus lourds que ceux âgés de 2 ans ($P < 0,0001$).

Le Tableau 7 montre la différence entre les quatre populations. La race Queue Fine de l'Ouest dans la région de Gafsa montre toujours les résultats les plus élevés par rapport aux autres races. Pour le poids corporel, les femelles Queue Fine de l'Ouest des deux régions ne présentent pas de différences significatives. Ceci pourrait s'expliquer par le fait que la race, originaire de l'Algérie, présente une bonne adaptation à cette région de la Tunisie, région très difficile du point de vue climatique. Pour la race D'man, les mesures trouvées concordent avec celles avancées par Ben Lakhal (1996) et Boujenane (1999); mais elles sont supérieures à celles de Boujenane (1990), ce qui laisse dire que les animaux D'man, originaires du Maroc et introduits en Tunisie dans les années 90, se sont bien adaptés aux oasis du Sud Tunisien.

Les béliers de la race Queue Fine de l'Ouest sont les plus grands de toutes les populations étudiées (Tableau 8). Les plus petits béliers sont ceux de la race D'man. Par ordre de classement, les hauteurs au garrot des béliers Queue Fine sont au premier rang suivies par celles de la race Barbarine et enfin les béliers D'man. Selon la longueur

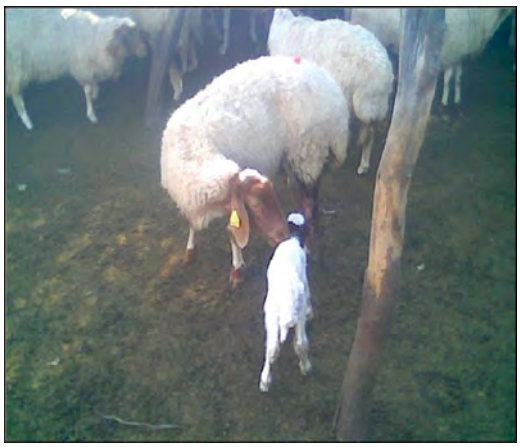

Figure 7. Brebis de race D'man (Tozeur).

Figure 9. Dendrogramme établi à partir des distances de Mahalanobis Calculées à partir de données quantitatives.

Tableau 4. Fréquences absolues (%) de la présence des cornes et des pendeloques en fonction de la race et du sexe des animaux.

Sexe	Femelle		Mâle	
	Corne	pendeloque	Corne	Pendeloque
Race				
BAR	13,4	0	4,55	0
QFG	12,16	18,24	63,15	43,85
QFT	4,25	42,55	70,31	34,38
DMN	0	41,29	0	16,27
Moyenne	**6,16**	**27,64**	**39,9**	**25,96**

Tableau 5. Statistiques descriptives de la population ovine du Sud Ouest de la Tunisie.

Variable	N	Moyenne	Ecart type	Minimum	Maximum
Age (ans)	986	3,89	1,83	1	9
HG (cm)	986	64,38	9,92	40	99
LC (cm)	986	92,02	8,84	71	126
PT (cm)	986	85,65	7,60	65	111
P♂ (kg)	208	69,24	7,15	50	84
P♀ (kg)	778	41,45	6,23	26	62

N: nombre d'animaux; HG: hauteur au garrot; LC: longueur du corps; PT: périmètre thoracique; P♂: poids des mâles; P♀: poids des femelles.

du corps des animaux, les individus enquêtés sont divisés en deux groupes, celui des plus longs, avec les deux races Queue Fine de Gafsa et D'man. Le deuxième groupe est formé des races Queue Fine de la région de Tozeur et la race Barbarine. On enregistre des valeurs presque égales du périmètre thoracique pour les populations Barbarine et D'man. La supériorité est toujours en faveur de la race Queue Fine dans la région de Gafsa (89,56 cm).

Pour le poids corporel, on remarque une nette supériorité de la race Queue Fine de l'Ouest par rapport aux autres races, indépendamment du sexe des animaux. Ce poids est de l'ordre de 73,33 kg pour les mâles et de 47,03 kg pour les femelles. Nos résultats sont similaires à ceux avancés par Haddad (1984).

Relations phylogénétiques entre races

Les distances de Mahalanobis entre les couples des populations sont regroupées dans le Tableau 9. Les distances trouvées entre les couples Barbarine–D'man et Queue Fine-D'man sont supérieures à celles trouvées entre les couples Barbarine-Que Fine de Gafsa et Barbarine-Queue Fine de Tozeur. La distance la plus élevée est enregistrée entre le couple D'Man-Queue Fine de Gafsa (20,24) suivi du couple D'Man-Queue Fine de

Tableau 6. Effet des facteurs du modèle utilisé sur les différents paramètres étudiés.

Source de variation	N	HG	LC	PT	P
Race					
BAR	79	$66,85 \pm 0,46^{a}$	$92,91 \pm 0,59^{a}$	$87,09 \pm 0,46^{a}$	$44,03 \pm 0,51^{a}$
QFG	148	$72,18 \pm 0,43^{b}$	$95,59 \pm 0,54^{b}$	$89,56 \pm 0,43^{b}$	$53,63 \pm 0,41^{b}$
QFT	141	$69,82 \pm 0,42^{c}$	$93,10 \pm 0,55^{a}$	$86,92 \pm 0,44^{a}$	$54,46 \pm 0,42^{b}$
DMN	310	$55,12 \pm 0,45^{d}$	$88,75 \pm 0,58^{c}$	$81,74 \pm 0,46^{c}$	$39,06 \pm 0,49^{c}$
Sexe		***	***	***	***
Femelle	208	$63,15 \pm 0,21^{a}$	$89,92 \pm 0,49^{a}$	$84,01 \pm 0,39^{a}$	$41,92 \pm 0,41^{a}$
Mâle	778	$74,11 \pm 0,38^{b}$	$101,43 \pm 0,27^{b}$	$94,39 \pm 0,22^{b}$	$66,05 \pm 0,27^{b}$
Age		NS	***	**	***
2	234	$68,22 \pm 0,38^{a}$	$94,23 \pm 0,51^{a}$	$88,42 \pm 0,41^{a}$	$51,96 \pm 0,41^{a}$
3	455	$68,91 \pm 0,40^{a}$	$96,16 \pm 0,49^{b}$	$89,49 \pm 0,41^{b}$	$55,22 \pm 0,39^{b}$
4	292	$69,21 \pm 0,40^{a}$	$96,64 \pm 0,49^{b}$	$89,69 \pm 0,41^{b}$	$54,78 \pm 0,39^{a}$
Sexe (race)		**	***	***	***
R^2		0,70	0,44	0,47	0,70

a,b,c,d Les moyennes de la même colonne suivies de lettres différentes sont significativement différentes.
*P < 0,05; **P < 0,001; ***P < 0,0001; NS : P > 0,05.
±: Erreur Standard.

Tableau 7. Moyennes des moindres carrés (± Erreur Standard) des variables quantitatives étudiées chez les femelles.

Variables	N	HG (cm)	LC (cm)	PT (cm)	P♀ (kg)
BAR	149	$64,48 \pm 0,41^{c}$	$90,77 \pm 0,42^{b}$	$85,20 \pm 0,42^{b}$	$40,53 \pm 0,46^{b}$
QFG	148	$69,17 \pm 0,46^{a}$	$92,33 \pm 0,59^{a}$	$87,05 \pm 0,87^{a}$	$47,03 \pm 0,78^{a}$
QFT	141	$66,67 \pm 0,49^{b}$	$90,41 \pm 0,63^{b}$	$83,91 \pm 0,50^{b}$	$45,93 \pm 0,78^{a}$
DMN	310	$54,07 \pm 0,32^{d}$	$86,97 \pm 0,41^{c}$	$80,13 \pm 0,33^{c}$	$35,89 \pm 0,61^{c}$

N: nombre d'animaux; HG: hauteur au garrot; LC: longueur du corps; PT: périmètre thoracique; P♀: poids des femelles.

Tableau 8. Moyennes des moindres carrés (± Erreur Standard) des variables quantitatives étudiées chez les mâles.

Variables	N	HG (cm)	LC (cm)	PT (cm)	P♂ (kg)
BAR	44	$76{,}94 \pm 0{,}18^{b}$	$102{,}09 \pm 1{,}04^{ab}$	$94{,}74 \pm 0{,}84^{ab}$	$65{,}29 \pm 1{,}21^{b}$
QFG	57	$79{,}86 \pm 0{,}72^{a}$	$103{,}78 \pm 0{,}92^{a}$	$95{,}74 \pm 0{,}74^{a}$	$73{,}33 \pm 0{,}77^{a}$
QFT	64	$76{,}60 \pm 0{,}68^{b}$	$97{,}51 \pm 0{,}88^{b}$	$92{,}55 \pm 0{,}69^{b}$	$73{,}25 \pm 0{,}72^{a}$
DMN	43	$63{,}39 \pm 0{,}83^{c}$	$103.33 \pm 1{,}06^{a}$	$94.83 \pm 0{,}85^{ab}$	$61.90 \pm 1{,}09^{b}$

N: nombre d'animaux; HG: hauteur au garrot; LC: longueur du corps; PT: périmètre thoracique; P♂: poids des mâles.

Tableau 9. Matrice des distances de Mahalanobis.

Population	BAR	QFG	QFT	DMN
BAR	0,000			
QFG	8,256	0,000		
QFT	6,838	5,371	0,000	
DMN	13,113	20,247	17,094	0,000

Tozeur (17,094) et enfin le couple D'man-Barbarine (13,11). La distance la plus faible est notée pour le couple Barbarine-Queue Fine. Le regroupement des races, établi par le dendrogramme des distances de Mahalanobis (Figure 9) montre deux branches principales. La première branche est celle contenant la race exotique D'man est la deuxième est celle qui regroupe les deux races locales. Cette dernière est à son tour divisée en deux sous branches représentant chacune une des deux races locales. En se basant sur les caractères morphologiques quantitatifs, nous avons trouvé que la race Barbarine est plus proche de la race Queue Fine de l'Ouest que de la race D'man, Ceci est expliqué certainement par la taille relativement petite de la race D'man par rapport aux deux autres races. Il est à signaler que les mensurations enregistrées sur la Barbarine sont proches de celles déterminées pour les animaux de la race Queue Fine de Tozeur et que la Queue Fine de Gafsa se distingue sur la base de ces caractères quantitatifs des animaux de toutes les autres races.

Conclusion

L'étude des caractères quantitatifs et qualitatifs a permis de déterminer la variabilité morphologique des trois races analysées au cours de cette étude. Une nette supériorité est détectée chez la race Queue Fine de l'Ouest au niveau des caractères hauteur au garrot, longueur du corps, périmètre thoracique et poids corporel comparativement aux races Barbarine et D'man. Tous ces caractères sont hautement influencés par la race et le sexe des animaux. Les fréquences des couleurs de la robe sont très variables et diversifiées, la couleur blanche est dominante chez les quatre races soit comme couleur unique soit en association avec d'autres colorations. Concernant la présence des cornes, les résultats montrent qu'en général les femelles des trois races ainsi que les mâles des races Barbarine et D'man sont mottes. La race Barbarine se distingue des autres races par l'absence totale de pendeloques alors que dans les autres races, des pendeloques peuvent être présentes.

Les distances génétiques calculées sur la base de ces caractères quantitatifs montrent que les distances trouvées entre les couples Barbarine–D'man et Queue Fine-D'man sont supérieures à celles trouvées entre les couples Barbarine-Queue Fine de l'Ouest.

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Morphological analysis and subpopulation characterization of Ripollesa sheep breed

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Summary
The Ripollesa sheep breed is an important Spanish local breed mainly located in the Mediterranean mountains and cultivated plains of Catalonia, exploited under semi-extensive production systems and currently intended for meat production. The morphological characterization of the Ripollesa breed was carried out from the study of eight flocks representative of different subpopulations. A total of 224 Ripollesa ewes and 17 rams were recorded for their live weight and 12 morphological measures, which were used for calculating 12 zootechnical indexes. Differences ($P < 0.05$) between flocks and sexes were revealed for several measures. A principal component analysis was performed on the morphological measures and revealed two main principal components accounting for 47.6 and 12.3 percent of the inertia, being related to the frame (body size and live weight) and to withers height and ear length, respectively. The cluster analysis allowed differentiating among four subpopulations with relevant implications to be taken into account for the breed conservation programme. The observed differences could be attributable to geographic location, selective history, flock management and genetics. The estimated zootechnical indexes classified the Ripollesa sheep breed as a medium-sized and long-shaped body frame, with a marked orientation to meat production and with signs of adaptation to the environment.

Keywords: *geographic variability, morphology, zoometry, zootechnical index*

Résumé
La race de moutons Ripollesa est une importante race locale espagnole qui vit principalement dans les montagnes méditerranéennes et dans les plaines cultivées de la Catalogne. Elle est exploitée dans des systèmes de production semi-extensive et actuellement destinée à la production de viande. La caractérisation morphologique de la race Ripollesa a été réalisée à partir de l'étude de 8 troupeaux représentatifs de différentes sous-populations. Au total, on a enregistré le poids vif et 12 mesures morphologiques de 224 brebis et de 17 béliers. Ces mesures ont été utilisées pour calculer 12 indicateurs zootechniques. Des différences ($P < 0{,}05$) dans plusieurs mesures ont été décelées entre les troupeaux et entre les sexes. Une analyse en composantes principales a été réalisée sur les mesures morphologiques et elle a révélé deux composantes principales qui constituent 47,6 et 12,3 pour cent de l'inertie, pourcentages liés respectivement au corps (taille et poids vif) et à la hauteur au garrot et la longueur des oreilles. L'analyse typologique a permis d'établir, entre quatre sous-populations, des différences qui ont des implications à prendre en considération dans le programme de conservation de la race. Les différences observées pourraient s'attribuer à l'emplacement géographique, à l'histoire de la sélection, à la gestion du troupeau et à la génétique. Les indicateurs zootechniques décrivent les moutons Ripollesa comme une race à corps de taille moyenne et à forme allongée, avec une orientation marquée pour la production de viande et présentant des signes d'adaptation à l'environnement.

Mots-clés: *indicateur zootechnique, morphologie, variabilité géographique, zoométrie*

Resumen
La raza ovina Ripollesa es una importante raza autóctona Española localizada principalmente en las montañas del Mediterráneo y en llanuras cultivadas de Cataluña, explotada bajo sistemas semi-extensivos de producción y actualmente destinada a producción de carne. La caracterización morfológica de la raza Ripollesa se llevó a cabo a partir del estudio de 8 rebaños representativos de diferentes subpoblaciones históricas. Un total de 224 hembras Ripollesas y 17 moruecos fueron caracterizados registrando su peso vivo y 12 medidas morfológicas, las cuales fueron utilizadas para el cálculo de 12 índices zoométricos. Diferencias ($P < 0.05$) entre rebaños y sexos fueron reveladas para varias medidas. El análisis de componentes principales realizado con las medidas morfológicas, reveló 2 componentes principales que contribuyen con 47.6 y 12.3 por ciento de la inercia, estando relacionados con el tamaño (tamaño corporal y peso vivo) y con la altura a la grupa y longitud de oreja, respectivamente. El análisis de clusters nos permitió diferenciar 4 subpoblaciones con implicaciones relevantes a ser tomadas en cuenta en el programa de conservación de la raza. Las diferencias observadas pueden atribuirse a la localización geográfica, historia selectiva, manejo del rebaño, y genética. Los índices zoométricos clasifican a la Ripollesa como una raza ovina de tamaño medio y longilínea, con una marcada orientación a la producción de carne y con signos de adaptación al ambiente.

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Palabras clave: *índice zoométrico, morfología, variabilidad geográfica, zoometría*

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Introduction

Livestock farming based on local breeds constitutes a very valuable animal industry from the economic, social and environmental points of view. Local breeds have remarkable special characteristics like resistance to prevailing diseases, fertility, maternal ability, longevity, adaptation to the environment and unique attributes of their final products, among others (García, 1980). Nevertheless, the increasing demand for animal products has led to an intensification of production systems and the subsequent restriction of the livestock industry to a few specialized breeds. This practice has reduced the use of local breeds and put their survival in danger (Oldenbroek, 1999), which is also the case of the Ripollesa breed. To overcome this problem, the Food and Agriculture Organization (FAO; http://www.fao.org) of the United Nations recommended establishing conservation programmes for the maintenance of animal genetic resources. Note that these programmes include, among other actions, the characterization of these local breeds.

Most of the native breeds of Spain included in the inventory of Spanish livestock breeds belong to the ovine species (Spanish Real Decreto 2129/2008, http://www.boe.es/boe/dias/2009/01/27/pdfs/BOE-A-2009-1312.pdf). The Ripollesa is the most abundant local sheep breed in Catalonia (Milán, Arnalte and Caja, 2003; Caja *et al.*, 2010), an Autonomous Community located in the NE of Spain. The breed is usually considered as being moderately prolific and is exploited for the production of "pascual"-type lambs (Guillaumet and Caja, 2001; Caja *et al.*, 2010). Indeed, previous studies reported both appealing productive (Torre *et al.*, 1989; Torre, 1991; Casellas *et al.*, 2007c) and reproductive (Casellas *et al.*, 2007a, 2007b) performance within the context of a remarkable adaptability to the geoclimatic conditions of the Mediterranean area (Guillaumet and Caja, 2001). Nevertheless, additional efforts to typify this breed become necessary, given that there is a substantial phenotypic heterogeneity that could even lead to different subpopulations (Torre, 1991).

Although the existence of different Ripollesa subpopulations was advocated by stakeholders for decades and suggested by different authors (Torre, 1991; Guillaumet and Caja, 2001), this hypothesis has never been tested. If true, this breed could suffer from a severe genetic structure (bottleneck) with important consequences on its effective population size and, by extension, on its conservation or even selection programme. These hypothetical subpopulations may have originated in different geographic areas and could differ in both, production and morphological traits, the latter being the main objective of our study.

In the present work, an attempt has been made to characterize the morphological diversity of the Ripollesa sheep breed, both between and within flocks. This research was performed on the basis of standardized morphological measurements and the subsequent calculation of zootechnical (ethnological and functional) indexes.

Material and methods

The Ripollesa breed

The Ripollesa sheep were described as a medium-sized breed with convex profile and characteristic pigmentation with black or brown spots on the head and legs (Sánchez-Belda and Sánchez-Trujillano, 1986; Guillaumet and Caja, 2001; Caja *et al.*, 2010). This breed belongs to the Spanish medium-fine (i.e. "entrefino") wool-type trunk with white wool and packed fleece (wool fibre diameter, 23–26 μm; Sánchez-Belda and Sánchez-Trujillano, 1986) (Figure 1). The breed is characteristically Mediterranean exploited under semi-extensive production systems in the mountains and cultivated plains of Catalonia and currently intended for meat production (Guillaumet and Caja, 2001; Caja *et al.*, 2010). Lambs are sold for slaughter as "pascual"-type (22–24 kg live weight; ∼12 kg carcass weight), usually directly by the sheep owners to the local butchers.

Most Ripollesa flocks are located in the provinces of Barcelona and Girona (Torre, 1991; Milán, Arnalte and Caja, 2003; Caja *et al.*, 2010), covering a wide range of

Figure 1. Grazing ewes of the Ripollesa sheep breed.

environments from plains to coastal mountains. This heterogeneity, and even geographic isolation, may have led to the evolution of the breed towards different subpopulations. Although this kind of population structure has never been properly studied in the Ripollesa breed, putative subpopulations have been suggested according to geographic locations (Torre, 1991; Guillaumet and Caja, 2001; Torres, 2007). Different names of these subpopulations are derived from particular localities in the area, their main features being the following (Table 1):

(1) Gosolenca, from Gòsol (Barcelona), horned ewes with large body size.
(2) Igualadina, from Igualada (Barcelona), non-horned ewes with scarce wool on the belly.
(3) Lluçanenca, from the Lluçanès (Barcelona), medium body size.
(4) Queralpina, from Queralbs (Girona), smaller and less prolific sheep with longer and the finest wool fibres.
(5) Hilarenca, from Sant Hilari Sacalm (Girona), the largest rams with long horns and presence of abundant hair in the wool in rams and ewes. Lambs are markedly hairy at birth.

Main differences among subpopulations should be expected with regard to body size and characteristics of wool and horns (Guillaumet and Caja, 2001).

Sheep samples

Morphological measurements were taken between September 2007 and June 2008, on adult Ripollesa animals (more than two years old) belonging to eight flocks registered in the official Flock-Book of the breed. Flocks were distributed across the geographic areas where the Ripollesa sheep are located (Figure 2), providing samples from the subpopulations described by Torre (1991) (Table 1).

Flocks 1–6 were commercial farms under semi-intensive production systems, whereas flocks 7 and 8 were experimental farms under intensive conditions. Sheep sampled from each flock consisted of 24–30 non-pregnant ewes and 0–4 rams taken at random from the older-than-two-year breeding stock; note that rams were produced in the same flock or acquired from the neighbour flocks. A total of 241 sheep (224 ewes and 17 rams) were included in the study, as detailed in Table 1.

Figure 2. Geographical location of the flocks (1: Cal Terrisco flock, 2: SGCE flock, 3: Las Parras de Martín flock, 4: Mas Muxach flock, 5: Montseny flock, 6: Cal Sabaté flock, 7: Mas Ros flock, 8: SEMEGA flock).

Morphological measurements

Morphological variables were measured by the same trained operator in the mornings, before the animals left the shelter to graze to avoid undesirable variations because of changes in live weight and rumen volumes. On the basis of Aparicio (1944), the following 12 morphological measures were taken on each animal (Figure 3):

(1) head length (HL), frontal distance from mouth to poll,
(2) head width (HW), maximum distance between zygomatic arches,
(3) ear length (EL), distance from the base to the tip of the right ear, along the dorsal surface,
(4) chest depth (CD), vertical distance from the top of the withers to the xyfoid process of the sternum,
(5) chest width (CW), maximum intercostal diameter at the level of the 6th rib, just behind the elbows,
(6) chest girth (CG), perimeter of the chest at the level of the 6th rib,
(7) withers height (WH), height from the top of the withers to the ground,
(8) back height (BH), height at the middle of the back, between the thoracic and the lumbar vertebrae,

Table 1. Description of the flocks and number of animals measured in each flock.

Flock	Flock location (village and province)	Subpopulation[1]	Flock size	Number of ewes measured	Number of rams measured
Cal Terrisco	Olost, Barcelona	Lluçanenca	550	30	–
SGCE	Bellaterra, Barcelona	Igualadina	140	29	4
Parras de Martín	Las Parras de Martín, Teruel	Igualadina	950	29	2
Mas Muxach	L'Estartit, Girona	Hilarenca and Gosolenca	438	27	3
Montseny	Osor, Girona	Hilarenca	610	24	4
Cal Sabaté	Nevà, Girona	Hilarenca and Queralpina	820	30	–
Mas Ros	Les Olives, Girona	Queralpina	964	27	2
SEMEGA	Monells, Girona	Queralpina	45	28	2

[1]The original types described in previous manuscripts were *Gosolenca*, *Igualadina*, *Queralpina* and *Hilarenca* (Torre, 1991; Guillaumet and Caja, 2001; Torres, 2007).

Figure 3. Zoometric measures. HL: head length; HW: head width; EL: ear length; CD: chest depth; CW: chest width; CG: chest girth; WH: withers height; HB: height at the middle of the back; BL: body length; RL: rump length; RW: rump width; CC: Cannon circumference.

(9) body length (BL), distance from the manubrium of the sternum to the pin,
(10) rump length (RL), distance from hip to pin,
(11) rump width (RW) maximum distance between left and right hurls,
(12) cannon perimeter (CP), perimeter of the right foreleg, between the knee and the pastern.

These variables were obtained using a ribbon measuring tape and a measuring stick for horses (Hauptner & Herberholz, Solingen, Germany). Additionally, live weight was recorded using fixed (SR2000, Tru-Test, Auckland, New Zealand) or portable FX1 (Iconix NZ, Oamaru, New Zealand) electronic scales.

Table 2. Definition of the zootechnical indexes calculated for each Ripollesa individual.

Indices	Type[1]	Calculation
Cephalic	Ethnological	HW/HL × 100
Thoracic	Ethnological	CW/CD × 100
Pelvic	Ethnological	RW/RL × 100
Corporal	Ethnological	BL/CG × 100
Dactyl thoracic	Functional	CC/CG × 100
Dactyl costal	Functional	CC/CW × 100
Relative depth of thorax	Functional	CD/WH × 100
Transversal pelvic	Functional	RW/WH × 100
Longitudinal pelvic	Functional	RL/WH × 100
Balance	Functional	(RW × RL)/(CD × CW)
Length	Functional	BL/WH
Cumulative	Functional	(W/μ)+balance index + length index

HL: head length; HW: head width; EL: ear length; CD: chest depth; CW: chest width; CG: chest girth; WH: withers height; HB: height at the middle of the back; BL: body length; RL: rump length; RW: rump width; CC: cannon perimeter; W: body weight; μ: estimated average for W.

[1]Ethnological indexes contributed general information about breed characteristics whereas functional indexes contributed information about the type, purpose and performance of the breed.

Zootechnical indexes

In order to evaluate the morphological characteristics of the Ripollesa breed, 12 zootechnical indexes were calculated according to Sotillo and Serrano (1985) and Alderson (1999). A definition of these indexes is shown in Table 2. Cephalic, thoracic, pelvic and corporal indexes are ethnological, which gave us general information about the breed characteristics in terms of describing structure and proportions (i.e. compactness, height, length and weight). The remaining indexes are functional, providing information about the type, aptitude and production performance of the animal. See Sotillo and Serrano (1985) and Alderson (1999) for a detailed description of the interpretation of the different zootechnical indexes.

Statistical analyses

All measurements and indexes were separately analysed under the following linear model:

$$Y_{ijk} = \mu + F_i + S_j + \varepsilon_{ijk}$$

where Y_{ijk} was the dependent phenotypic record, μ was the population mean, F_i was the effect of the flock (1–8), S_j was the effect of the sex (1 or 2) and ε_{ijk} was the residual term. Flock effects were contrasted by a one-way ANOVA test followed by the Student Newman–Keuls multiple comparison test, implemented in the General Linear Model procedure of SAS 9.1 (SAS Institute Inc., Cary, NC, USA).

The residuals obtained from the previous analyses on morphological measurements were used for a principal component analysis (PCA) performed by the SPAD 5.5 (2002) software (Coheris, Suresnes, France). For all subsequent analyses, only data from ewes were used because of the small number of rams contributing to this study. This analysis allowed us to understand the differences among flocks with regard to morphological measures, where only principal components accounting for more than 10 percent of the phenotypic variance were retained.

On the basis of the estimates from the PCA analysis, a discriminant analysis (SPAD 5.5) was conducted to estimate the proportion of animals that were properly classified into their own flock. This was an additional way of evaluating within-flock resemblance and the degree of differences between flocks. As a final step, a cluster analysis (SPAD 5.5) was performed for classification of data to establish the optimum number of groups (i.e. subpopulations) based on the number of principal components accounting for at least 80 percent of the total inertia. Between-group differences of morphological measures were compared by means of a Student Newman–Keuls multiple comparison test (SAS 9.1).

Results and discussion

Morphological diversity between sexes and flocks

According to the values reported in this study, the Ripollesa breed showed a marked sexual dimorphism, as rams (Figure 4) were larger than ewes (Figure 5) for almost all measurements ($P < 0.05$), except for ear length and rump width (Table 3). Sexual dimorphism is a fundamental morphological characteristic of most ungulates (Andersson, 1994), and has important consequences for ecology, behaviour, population dynamics and evolution (LeBlanc, Festa-Bianche and Jorgenson, 2001).

It is expected that all animal populations have certain variability between groups or subpopulations, these differences being of great importance to improve performance by selection. In our study, a moderate variability (CV ranging between 4 and 13 percent) in all the morphological measures considered was observed for the whole ewe sample (Table 3). The highest CVs were for live weight (12.9 percent), chest width (10.0 percent), ear length (7.7 percent), chest depth (6.9 percent), rump length (6.9 percent) and rump width (6.5 percent). Despite this, the greatest differences between average estimates for each flock with respect to the overall means were reported for withers height (65.3–73.2 cm; 11.4 percent), chest depth (26.6–32.9 cm; 20.5 percent), rump width (19.8–22.9 cm; 14.2 percent), head width (12.5–14.7 cm; 15.9 percent) and ear length (12.5–14.5 cm; 14.8 percent) (Table 4). These differences could be attributed to the geographic location and specific feeding conditions of each flock, combined with morpho-structural differences that may have a genetic origin.

We compared the Ripollesa breed with breeds located in neighbour geographical areas to characterize this breed and highlight differences and similarities with related breeds; Ripollesa ewes had greater morphological measures, mainly regarding head width, rump length, rump width and body length, than those reported for the Canaria (Alvarez *et al.*, 2000a), Gallega (Sánchez *et al.* 2000), Palmera (Alvarez *et al.*, 2000b), Xisqueta (Avellanet, 2006), Yankasa and Wad (Salako, 2006) sheep breeds.

Figure 4. Ram of the Ripollesa sheep breed.

Figure 5. Ewe of the Ripollesa sheep breed.

Principal components analysis

The principal components analysis allowed us to spatially characterize the relationships among sheep from different flocks according to a plane delimited by two main axes, PC1 and PC2, which accounted for 47.6 and 12.3 percent of the phenotypic variance, respectively, (Figure 6). As suggested by Table 5, the PC1 axis could be linked to the variables related to greater diameter amplitude and heavier live weight of the animals, whereas the PC2 axis gave a major relevance to their height and ear length of animals. Although individuals from the same flock tend to be plotted together, some flocks overlapped in Figure 6, which would suggest a common origin or belonging to the same subpopulation. Indeed, it would be possible to suggest that Mas Muxach ewes (#3) were the largest framed and heaviest individuals, SEMEGA (#7) had the smallest and lightest ewes, and Montseny (#5) and Las Parras de Martín (#6) ewes were the tallest (Table 4; Figure 6). Nevertheless, the results from the PCA did not allow for a clear-cut grouping of all of the different flocks and showed a remarkable degree of heterogeneity. Overlapping shown in Figure 6 could be due to the exchange of breeding stock between flocks (ANCRI, personal communication), which would suggest that current flocks could be a mixture of animals from different origins with a heterogeneous contribution from each original subpopulation (Torre, 1991). Nonetheless, this hypothesis does not invalidate the presence of several subpopulations derived from one or several ancient subpopulations.

Discriminant and cluster analyses

The results from the discriminant analysis (Table 6) confirmed this partial overlapping as the percentage of individuals correctly classified into their own flock ranged

Table 3. Mean, coefficient of variation (CV), minimum value (Min.) and maximum value (Max.) of the morphometrical measures.

Variables	Ewes				Rams mean
	Mean	CV	Min.	Max.	
Head length, cm	23.7[a]	4.4	21	28	26.8[b]
Head width, cm	13.8[a]	4.5	11	17	15.4[b]
Ear length, cm	13.5[a]	7.7	10	16	13.2[a]
Chest depth, cm	30.7[a]	6.9	20	42	34.1[b]
Chest width, cm	18.8[a]	10.0	12	28	21.2[b]
Chest girth, cm	90.4[a]	5.1	75	108	100.9[b]
Withers height, cm	69.4[a]	4.4	58	80	75.9[b]
Height at the middle of the back, cm	68.2[a]	4.3	56	77	74.5[b]
Body length, cm	75.6[a]	5.3	43	85	84.1[b]
Rump length, cm	24.2[a]	6.9	15	29	26.5[b]
Rump width, cm	21.8[a]	6.5	16	29	22.5[b]
Cannon perimeter, cm	8.6[a]	6.1	7.5	10	10.0[b]
Weight, kg	51.4[a]	12.9	25	80	75.1[b]

Means with the same superscript did not differ significantly ($P > 0.05$) between sexes.

between 70 and 100 percent, with only 18.7 percent of the animals, on average, being classified in wrong flocks. The high percentages of matching suggested a marked degree of differentiation among flocks, being the greatest in the SEMEGA (#7) flock in which 100 percent of their own ewes were assigned correctly and only two ewes more from other flocks were incorrectly assigned to this flock.

On the other hand, the cluster analysis defined four sheep groups, each represented mainly by the following flocks (number of ewes and percentage of matching):

(1) Group 1 (19.6 percent of the ewes): Mas Muxach (24 ewes, 89 percent) and SGCE (13 ewes, 45 percent), characterized by being heavy and large framed animals.
(2) Group 2 (17.9 percent of the ewes): Montseny (13 ewes, 54 percent) and Las Parras de Martín (13 ewes, 45 percent), characterized mainly by being tall animals.
(3) Group 3 (40.6 percent): Cal Sabaté (20 ewes, 67 percent), Cal Terrisco (20 ewes, 67 percent) and Mas Ros (14 ewes, 52 percent), characterized by including animals with intermediate frame and long ears.
(4) Group 4 (21.9 percent): SEMEGA (24 animals, 86 percent), with the smallest body size (Table 7).

This grouping can be justified in part by the different subpopulations that contributed to the studied flocks. Although the Montseny and Las Parras de Martín flocks must have come from the same original subpopulations as do Mas Muxach and SGCE (Hilarenca and Igualadina subpopulations), they are characterized by having a greater height than the general average. Even assuming a common origin, departures between Groups 1 and 2 must be

Table 4. Average of the morphological measures and live weight of Ripollesa ewes of flocks of different origins.

	CU	UA	PM	JM	OS	CS	MR	DG	RMSE[1]
Number of animals	30	29	29	27	24	30	27	28	
Head length, cm	22.8[a]	23.2[a]	24.9[b]	24.1[c]	25[b]	24[c]	23.3[a]	22.2[d]	1.1
Head width, cm	13.7[ab]	13.7[ab]	14.1[ac]	14.7[d]	13.6[b]	14.3[c]	13.7[ab]	12.5[e]	0.6
Ear length, cm	12.9[ab]	13.8[cd]	14.5[e]	12.5[a]	13.4[bc]	14.1[cde]	14.2[ce]	13[ab]	1.1
Chest depth, cm	29.8[ab]	32[c]	32.4[c]	32.9[c]	32.2[c]	30.8[b]	28.8[a]	26.6[d]	2.0
Chest width, cm	16.8[a]	20.7[b]	18.24[cd]	22.4[e]	19.4[d]	18.8[d]	16.9[a]	17.3[cd]	1.9
Chest girth, cm	89.1[a]	95.4[b]	89.2[a]	100.1[c]	90.5[a]	89[a]	87.6[a]	82.7[d]	4.6
Withers height, cm	68.2[a]	68.9[ab]	70.8[bc]	71.2[c]	73.2[d]	69[ab]	69.1[ab]	65.3[e]	3.1
Height at the middle of the back, cm	67.4[a]	67.7[ab]	69.1[ab]	69.7[c]	72.1[a]	67.9[ab]	68.1[ab]	64.3[d]	2.9
Body length, cm	73.4[a]	74.7[ab]	78.8[c]	78.3[c]	77.0[cb]	77.1[cb]	74.9[ab]	71.1[d]	4.1
Rump length, cm	23.2[a]	25.6[ab]	25.6[ab]	24.5[b]	25.9[b]	24.9[ab]	24.1[ab]	19.9[c]	3.5
Rump width, cm	22.1[ab]	22.9[b]	20.5[cd]	24[e]	22.5[b]	21.4[a]	21.3[ad]	19.8[c]	1.4
Cannon perimeter, cm	8.4[a]	8.5[a]	8.4[a]	9.2[b]	9[bc]	8.4[a]	8.8[ac]	8.4[a]	0.5
Weight, kg	49.1[a]	58.3[b]	51.2[a]	61.5[b]	59.4[b]	51[a]	44.2[c]	37.9[d]	6.6

Flock of origin = CU, Cal Terrisco; UA, SGCE of the Universitat Autònoma de Barcelona; PM, Las Parras de Martín; JM, Mas Muxach; OS, Montseny; CS, Cal Sabaté; MR, Mas Ros; DG: SEMEGA, Diputació de Girona.
[1]RMSE: root mean square error.
Means with the same superscript did not differ significantly ($P > 0.05$).

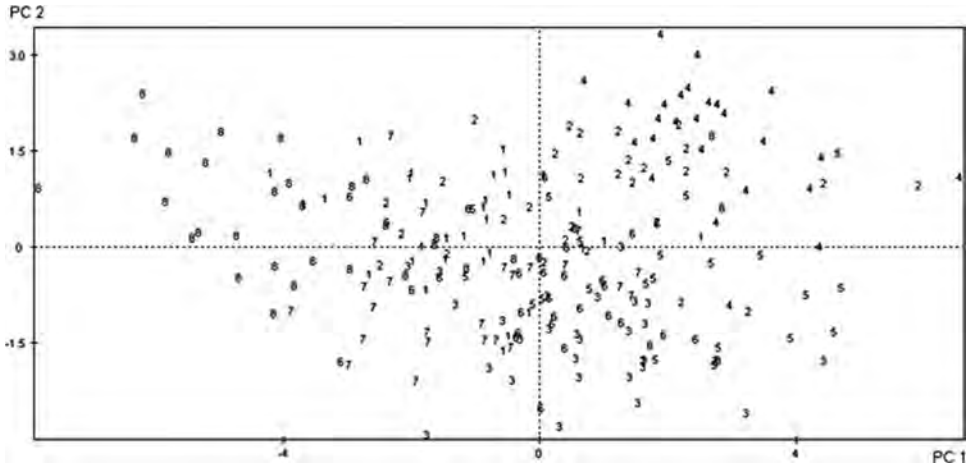

Figure 6. Representation of active individuals on the principal components (PC1 and PC2) space (1: Cal Terrisco flock, 2: SGCE flock, 3: Las Parras de Martín flock, 4: Mas Muxach flock, 5: Montseny flock, 6: Cal Sabaté flock, 7: Mas Ros flock, 8: SEMEGA flock).

Table 5. Eigenvectors from the principal components analysis performed on the morphological measurements.

	PC 1[1]	PC 2
Head length, cm	0.26	0.09
Head width, cm	0.22	0.25
Ear length, cm	0.15	0.22
Chest depth, cm	0.25	−0.03
Chest width, cm	0.24	−0.42
Chest girth, cm	0.40	−0.40
Withers height, cm	0.33	0.44
Height at the middle of the back, cm	0.33	0.46
Body length, cm	0.28	−0.06
Rump length, cm	0.27	−0.03
Rump width, cm	0.26	0.05
Cannon perimeter, cm	0.27	−0.11
Live weight, kg	0.36	−0.35

[1]PC: principal component; PC1 accounted for 47.6 percent of the variance and PC2 accounted for 12.3 percent of the variance.

probably linked to variable contributions from the Hilarenca and Igualadina historical subpopulations and an independent evolution during several years or decades. Focusing on Group 3, it was expected that animals from Cal Sabaté flock had a medium size, because this flock derived from original Hilarenca and Queralpina subpopulations, although differing from flocks assigned to Groups 1 and 2; in a similar way, the Cal Terrisco flock (Lluçanenca subpopulation) and *Mas Ros* flock (Queralpina subpopulation) were assigned to this Group 3. Nevertheless, there are also animals from the original Queralpina subpopulation in the group of SEMEGA ewes, the smaller individuals of the Ripollesa breed reported.

Within this context, the morphological characteristics of the historical subpopulations are still present in current morphological groups, although influences from more than one subpopulation could be found in the same flock and independent evolutionary patterns would have led to different subpopulations although departing from the same original genetic background. This makes evident the moderate-to-low genetic flow between flocks, where some specific morphotypes were preferentially preserved in each flock. In consequence, a substantial genetic structure could be anticipated in the Ripollesa populations, increasing the complexity of a conservation programme.

Table 6. Number of animals and corresponding percentage classified into each flock from the discriminant analysis.

	CU[1]	UA	PM	JM	OS	CS	MR	DG	Total
CU	25 (83.3)[2]	2 (6.7)	0	1 (3.3)	0	1 (3.3)	0	1 (3.3)	30
UA	2 (6.9)	21 (72.4)	1 (3.5)	4 (13.8)	0	1 (3.5)	0	0	29
PM	0	0	25 (86.2)	0	0	4 (13.8)	0	0	29
JM	1 (3.7)	2 (7.4)	0	23 (85.2)	0	1 (3.7)	0	0	27
OS	0	0	2 (8.3)	2 (8.3)	19 (79.2)	1 (4.2)	0	0	24
CS	1 (3.3)	3 (10)	3 (10.0)	0	1 (3.3)	21 (70)	1 (3.3)	0	30
MR	3 (11.1)	1 (3.7)	0	0	0	1 (3.7)	20 (74.1)	2 (7.41)	27
DG	0	0	0	0	0	0	0	28 (100)	28
Total	32	29	31	30	20	30	21	31	224

Flock of origin = CU, Cal Terrisco; UA, SGCE of the Universitat Autònoma de Barcelona; PM, Las Parras de Martín; JM, Mas Muxach; OS, Montseny; CS, Cal Sabaté; MR, Mas Ros; DG: SEMEGA, Diputació de Girona.

[1]Rows indicate the flock-of-origin of the animals whereas columns indicate the flock where each animal is assigned.

[2]Number of animals correctly classified and corresponding percentage (rounded off within parentheses to the nearest unit).

Table 7. Means of the variables studied in females of each group of Ripollesa sheep breed.

	Group 1	Group 2	Group 3	Group 4
Number of animals	56	53	87	28
Head length, cm	23.6[a]	24.9[b]	23.3[a]	22.2[c]
Head width, cm	14.2[a]	13.9[a]	13.9[a]	12.5[b]
Ear length, cm	13.2[a]	14.0[b]	13.7[b]	13.0[a]
Chest depth, cm	32.4[a]	32.3[a]	29.8[b]	26.6[c]
Chest width, cm	21.5[a]	18.8[b]	17.5[c]	17.3[c]
Chest girth, cm	97.7[a]	89.8[b]	88.6[b]	82.7[c]
Withers height, cm	70.0[a]	71.9[b]	68.8[a]	65.3[c]
Height at the middle of the back, cm	68.7[a]	70.5[b]	67.8[a]	64.3[c]
Body length, cm	76.5[ab]	78.0[a]	75.1[b]	71.1[c]
Rump length, cm	25.1[a]	25.7[a]	24.1[b]	19.9[c]
Rump width, cm	23.4[a]	21.4[b]	21.6[b]	19.8[c]
Cannon perimeter, cm	8.8[a]	8.7[ab]	8.5[bc]	8.4[c]
Weight, kg	59.9[a]	54.9[b]	48.2[c]	37.9[d]

Means with the same superscript did not differ significantly ($P > 0.05$).
Group 1: Mas Muxach and SGCE flocks; Group 2: Montseny and Las Parras de Martín flocks; Group 3: Cal Sabaté, Cal Terrisco and Mas Ros flocks; Group 4: SEMEGA flock.

Differences among flocks were also found by Avellanet (2006) in ewes of the Xisqueta breed, where the values of the morphological measures varied depending on the location of the flocks, management and feeding, among others. Also Kunene, Nesamvuni and Fossey (2007) found that the location of the flocks had a significant effect on the morphological measures of Zulu ewes. In this study, however, it is possible that the differences among flocks could also have a genetic origin because some of the differences among the hypothetical subpopulations of origin are retained when the flocks are reared in other areas.

Zootechnical indexes

The calculation and analysis of the different zootechnical indexes allowed us to ethnologically classify the Ripollesa sheep breed (Table 8). On the basis of the cephalic index, the Ripollesa showed to be a dolichocephalic breed, because the length of the head predominated over the width. Both the thoracic and the length indexes allowed us to classify the breed as long shaped, whereas the pelvic index indicated that it is a convex breed, with the rump length predominating in relation to its amplitude. The breed had a medium frame according to the dactyl-thoracic and dactyl-costal indexes. These results agreed with the visual valuations of Torre (1991) and Guillaumet and Caja (2001). The relative depth of the thoracic index indicated that the breed is suitable for meat production, lower values indicating better meat aptitude (Aparicio, 1944), in agreement with Daza (1997), Guillaumet and Caja (2001) and Milán, Arnalte and Caja (2003). This index also indicated that the length of the legs suggests that the breed had good adaptation to the environmental conditions under which it is raised. The transversal pelvic and longitudinal pelvic indexes also provided information about the aptitude of the animal, supporting the Ripollesa as a sheep breed for meat production, which reinforces the results obtained from the calculation of the cumulative index.

Given that some of the indexes gave the same information, we suggest simplifying the number of analysed indexes for the future to the following ones: thoracic, cephalic, pelvic,

Table 8. Mean, standard deviation (SD), coefficient of variation (CV), standard error (SE), minimum value (Min.) and maximum value (Max.) of the calculated zootechnical indexes.

Indices	Mean	SD	CV	SE	Min.	Max.
Cephalic	58.4	3.7	6.3	0.2	48.0	76.2
Thoracic	61.5	8.1	13.2	0.5	41.4	87.1
Pelvic	90.8	9.8	10.8	0.5	73.1	129.4
Corporal	83.9	6.1	7.3	0.3	47.8	101.2
Dactyl thoracic	9.6	0.7	7.3	0.0	7.8	11.7
Dactyl costal	46.6	6.1	13.0	0.3	30.8	69.2
Relative depth of thorax	44.2	3.7	8.3	0.2	29.4	60.3
Transversal pelvic	31.4	2.5	8.0	0.1	26.4	38.7
Longitudinal pelvic	34.9	3.1	8.9	0.2	23.8	43.3
Balance	0.9	0.1	15.6	0.0	0.5	1.4
Length	1.1	0.1	5.8	0.0	0.6	1.3
Cumulative	3.0	0.2	7.2	0.0	2.0	3.6

dactyl thoracic and relative depth of thorax. These subsets of indexes are enough to ethnologically classify the breed and also to provide information about the productive purposes of the Ripollesa breed.

Average differences between flocks and subpopulations of Ripollesa relied on sheep size, weight and height. The cluster analysis suggested four differentiated groups, although there were ewes that could not be assigned to a particular group. The results of the analysed indexes allowed us to classify the Ripollesa sheep breed as medium framed and convex, predominantly suitable for meat production.

Note that our results contribute essential information to characterize this meat-type breed following FAO recommendations, and has become a relevant source of basic information to support the conservation and selection programme of the Ripollesa sheep breed.

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Phenotypic and morphological characterization of indigenous chicken populations in southern region of Ethiopia

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Summary

Phenotypic characterization of indigenous chicken resources is a prerequisite for their rational utilization. Data were collected from 748 randomly selected households (HHs) using structured questionnaires. Visual appraisal was conducted to study morphological traits of indigenous chicken populations. Quantitative data were collected on body weight and shank length from both sexes. The results indicated that 55.0 percent of chicken populations were single combed followed by rose (28.5 percent) and pea (15.2 percent) combs. Yellow was the major shank colour (52.5 percent), followed by white (29.1 percent) and black (14.7 percent). About 46.4, 34.2 and 19.4 percent of chicken populations exhibited red, white and yellow earlobes, respectively. The predominant plumage colour was Kei (36.6 percent) followed by Tikur (20.7 percent), Gebsima (15.3 percent), Netch (12.3 percent), Kokima (8.4 percent), Wosera (3.7 percent), Zigrima (1.7 percent) and Zagolima (1.3 percent). The highest adult body weight was found in Naked-neck chickens (1.7 kg), followed by Kei (1.5 kg), Gebsima (1.45 kg) and Wosera (1.46 kg). The Naked-neck and Wosera males had the longest shank of 115 and 113 mm, respectively. Kei male chickens had large body weight shank length ratio compared with other indigenous chickens. The present study suggests that indigenous chicken populations might possess useful genetic potentials for improved productivity under scavenging feed resource-based production systems.

Keywords: *phenotypic characterization, indigenous chickens, Southern Ethiopia, administrative zones, agroclimatic zones*

Résumé

La caractérisation phénotypique des ressources génétiques des poules indigènes est une condition préalable à leur utilisation rationnelle. On a réuni les données à partir de 748 ménages choisis au hasard, en utilisant des questionnaires structurés. On a conduit un examen visuel des populations de poules indigènes pour étudier leurs caractères morphologiques. Les données quantitatives sur le poids corporel et sur la longueur des tarses des mâles et des femelles ont été rassemblées. Les résultats indiquent que 55,0 percent des poules n'ont qu'une seule crête, que pour 28,5 percent la crête est rose et, pour 15,2 percent, elle est en pois. Les tarses sont principalement jaunes (52,5 percent), ensuite blancs (29,1 percent) et noirs (14,7 percent). Environ 46,4, 34,2 et 19,4 percent des populations de poules présentent respectivement des lobes auriculaires rouges, blancs et jaunes. La couleur prédominante du plumage est Kei (rouge, 36,6 percent), Tikur (noir, 20,7 percent), Gebsima (gris, 15,3 percent), Netch (blanc, 12,3 percent), Kokima (8,4 percent), Wosera (3,7 percent), Zigrima (1,7 percent) et Zagolima (1,3 percent). Le poids corporel le plus élevé est celui des poules Naked Neck (1,7 kg), ensuite des Kei (1,5 kg), des Gebsima (1,45 kg) et des Wosera (1,46 kg). Les mâles Naked Neck et Wosera ont les tarses les plus longs, respectivement de 115 et de 113 mm. Les mâles Kei ont une proportion poids corporel/longueur des tarses considérable par rapport aux autres poules indigènes. Cette étude suggère que les poules indigènes possèdent probablement des potentialités génétiques utiles qui permettraient d'accroître la productivité dans le cadre des systèmes de production basés sur les ressources résiduelles.

Mots-clés: *caractérisation phénotypique, poules indigènes, sud de l'Ethiopie, zones administratives, zones agroclimatiques*

Resumen

Caracterización fenotípica de los recursos locales aviares es un requisito previo para su utilización racional. Se ha recopilado información de 748 familias seleccionada al azar (HHs, por sus siglas en inglés) por medio de cuestionarios. Se ha llevado a cabo una evaluación visual con objeto de estudiar las características morfológicas de las poblaciones locales de gallinas. Los datos cuantitativos han sido obtenidos a partir del peso corporal y de la longitud del tarso en ambos sexos. Los resultados señalaron que el 55 percent de población de gallinas presenta cresta sencilla, seguida del tipo de rosa (28,5 percent) y guisante (15,2 percent). El colour mayoritario de los tarsos es el amarrillo (52,5 percent), seguido por el blanco (29,1 percent) y el negro (14,7 percent). El 46,4, 34,2 y 19,4 percent de las poblaciones de gallina estudiada presenta orejillas de colour rojo, blanco y amarillo, respectivamente. El colour del plumaje predominante es el Kei (36,6 percent), seguido de Tikur (20,7 percent), Gebsima (15,3 percent), Netch (12,3 percent), Kokima (8,4 percent), Wosera (3,7 percent), Zigrima (1,7 percent) y Zagolima (1,3 percent). El peso más alto en ejemplares adultos lo han presentado los individuos de cuello desnudo (1,7 Kg.), seguido por los Kei (1,5 Kg.), Gebsima (1,45 kg) y Wosera (1,46 kg). Los ejemplares macho de cuello desnudo y los Wosera son los que han presentado tarsos con mayor longitud, de 115 y 113 mm., respectivamente. Los machos de las gallinas Kei presentaban una longitud corporal y del tarso mayor que otras gallinas indígenas. El presente

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estudio señala que las poblaciones de gallinas autóctonas podrían ser potencialmente útiles genéticamente para mejorar la productividad bajo sistemas de producción basado en alimentación procedente de residuos.

Palabras clave: *Caracterización fenotípica, gallinas indígenas, Sur de Etiopía, zonas administrativas, zonas agroclimáticas*

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Introduction

Many of the world's poor depend directly on genetic, species and ecosystem biodiversity for their livelihoods. In many regions, farm animal genetic resources (FAnGR) are a vital component of this biodiversity (Anderson, 2003). In developing countries, some 70 percent of the world's rural poor (2 billion people) depend on livestock as an important component of their livelihoods (Hoffmann and Scherf, 2005). Genetic erosion of domestic animal diversity has placed 20 percent of the world's breeds at risk of extinction (FAO, 2007). The FAO (1997, 2007) recommends the conservation and sustainable development of FAnGR focusing on the many 'adaptive' breeds that survive well in the low external input agriculture typical of developing countries.

Identification and characterization of the chicken genetic resources generally requires information on their adaptation to a specific environment, possession of unique traits of current or future economic value and socio-cultural importance, which are crucial inputs to decisions on conservation and utilization (Weigend and Romanov, 2001). Most of the indigenous chickens have evolved through adaptation to various agroclimatic conditions. They possess gene combinations and special adaptations not found in other improved modern breeds (Egahi *et al.*, 2010). Variations in major morphological traits such as outline and feather contours, shank and ear-lobe colours, comb types are common among indigenous chicken populations (Teketel, 1986). These characteristics provide a basis for grouping according to their phenotypic and morphological appearances. According to CSA (2001), the chicken populations of Ethiopia in the year 2000 was estimated at 37.76 million. Three years later, estimates of the indigenous chicken populations were 36 million in 2003, excluding the whole Gambela Region (CSA, 2004). Currently, there are about 42 million chickens in the country, of which 96.6 percent are indigenous chickens (CSA, 2009), indicating the significance of local chickens as potential FAnGR in the country.

The unique adaptation features and morphological variations of Ethiopian indigenous chicken population have been recently reported by several scholars. Halima *et al.* (2007b) reported the phenotypic variation of indigenous chicken populations in northwest Ethiopia. Similarly, studies conducted by Duguma (2006) and Dana *et al.* (2010) were focused on the characterization of indigenous chicken populations found at specific locations that may not necessarily represent the genetic resources of indigenous chickens distributed in the whole country in general and in southern region of Ethiopia in particular. Thus, the indigenous chicken populations in the southern Ethiopia are neither phenotypically nor genotypically properly characterized for a defined purpose at their habitation. Their genetic potential still remains undefined forming a major barrier for the development and implementation of suitable genetic improvement strategies at a national level. The fundamental objective of this work was thus to describe the phenotypic and morphological variations of indigenous chicken populations that are found in southern Ethiopia.

Material and methods

Description of the survey region

This study was carried out in Southern Nations, Nationalities and People's Regional State (SNNPRS) on 13 administrative zones and six special woredas (Figure 1). The region is located in the southern and southwestern part of Ethiopia. Astronomically, it roughly lies between 4°43′–8°58′ north latitude and 34°88′–39°14′ east longitudes. It is bordered with Kenya in south and the Sudan in southwest. The total area of the region estimated to be 110,931.9 km^2, which is 10 percent of the country and inhabited by a population size of about 16 million accounting nearly 20 percent of the total population of the nation. The population density of the region is 142 persons per km^2 and is one of the most densely populated parts of the country. With less than one in ten of its population living in urban areas (8.9 percent) in 2008, the region is overwhelmingly rural (www.rippleethiopia.org/page/snnpr).

Procedures of data collection and analysis

Sampling technique

This study was carried out using structured questionnaires and field surveys in 13 administrative zones and six special woredas found in the region for about four consecutive years between 2005 and 2009. The woredas found in each administrative zone were stratified according to the main agroclimatic zones, i.e. *Kolla* (lowland), *Woina Dega* (midland) and *Dega* (highland) with altitudinal ranges of <1500, 1500–2500 and >2500 m a.s.l, respectively. The field survey covered 54 woredas, 193 peasant associations (10 percent of the total) and 748 purposely

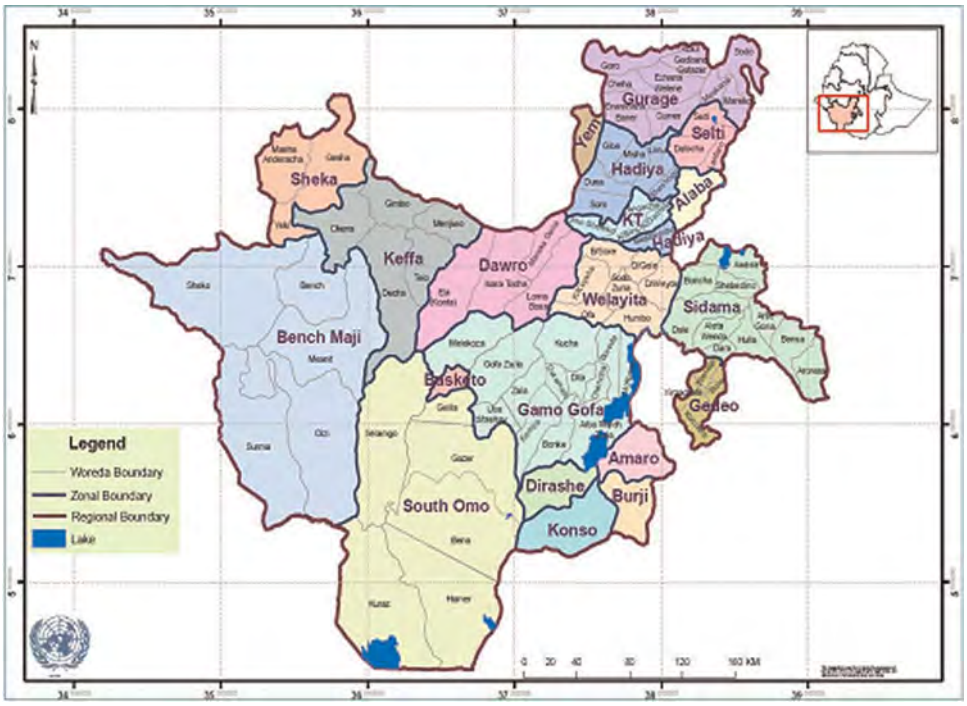

Figure 1. Map of Southern Nations Nationalities and Peoples Regional State (SNNPRS) displaying administrative zones and special woredas (districts) covered by the survey (retrieved at: www.rippleethiopia.org/page/snnpr).

but randomly selected households (HHs) (10 percent of the total) who keep five or more indigenous chickens within the HH. The number of chickens sampled for the study varies across zones depending upon the human and chicken population density of each administrative zone.

Morphological traits

A structured questionnaire was designed to collect data both on poultry production system of the region (Melesse and Negesse, unpublished data) and variations in basic phenotypic and morphological traits. Before the commencement of the survey, the questionnaires were pretested using sample HHs and appropriate adjustments were made on specific contents. The interviews were conducted at farmers' houses with the assistance of local agricultural extension officers drawn from each woreda.

Moreover, visual appraisal on the appearance of indigenous chicken populations and their typical morphological features were conducted together with the farmers, agricultural extension experts and two employee of this research project (graduate of public University in the field of General Agriculture). Special training was given to the project employees by researchers on basic phenotypic and morphological traits of poultry. Moreover, researchers were actively involved in all field survey activities throughout the study period.

To simplify the process of phenotypic evaluation, a copy of colour pictures showing the basic comb types and other morphological traits was used during each appraisal process. Furthermore, over 1000 pictures on indigenous chickens were taken during field visits from 39 market sites and villages of the surveyed regions. These pictures were used to crosscheck and validate the descriptions given by farmers from each HH. Moreover, a catalogue of basic plumage colours and feather patters is being prepared for future reference.

Phenotypic and morphological variations were studied based on feather morphology, feather distribution and patterns, plumage colours, shank colour, earlobe colour and comb types. Data were recorded for a total of 3770 indigenous chickens of both sexes following the FAO descriptors for chicken genetic resources (FAO, 1986, 2007). Moreover, a total of 1876 eggs were used for the evaluation of egg shell colours. Descriptions of comb types were based on illustrations presented by Somes (2003), Ensminger (1992) and Roberts (1997). Feather patterns and distribution on shank and feet as well as muff and beard features were described based on illustrations by Batty and Francis (1979) and Roberts (1997).

Quantitative traits

During field visits, quantitative data were collected on live weight and shank length from both sex groups sampled from 13 administrative zones. These measurements were taken from 2340 adult chickens whose age was approximately 36 weeks or above. This age was chosen by considering the slow maturation of indigenous chickens to reach their adult age. The birds' age was determined by "recalling method" of interviewed farmers. (Women farmers can easily recall the age of their chickens because of the long time interval between two consecutive clutches in indigenous chickens.) Live body weight was taken using

digital weighing balance to the nearest of 0.05 g (Model: DT 5k, LARK®). Shank length was measured from the top of the flexed hock joint to the bottom of the footpad using digital calipers to the nearest of 0.05 mm. The body weight shank ratio was then calculated as an index of bird density (Griffin *et al.*, 2005).

Statistical analysis

Shell colour, comb type, shank colour, earlobe colour, plumage colours, feather distribution and morphology were analyzed using descriptive statistics and compared as percentages without application of statistical tests. General Linear Models Procedure of SAS® (SAS Institute, 1996) was used to analyze the analysis of variance of the quantitative data, fitting live weight, shank length and body weight shank length ratio as dependent variables, whereas sampling zones (the populations), indigenous chickens with various plumage colours and sex of the chickens as fixed factors. When differences were significant, comparisons of means were done by using Duncan's multiple range test. All statements of statistical differences in quantitative data were based on $p < 0.05$ unless noted otherwise.

Results

Flock size and distribution

A total of 7184 chickens were reported from 748 HHs in the surveyed areas, of which 40.2 percent were male and the rest (59.8 percent) were female chickens. Among them, 10.5 percent males and 18.7 percent females were reported as replacement stock for breeding purposes. Of the total chicken populations, 18.5, 51.9 and 29.6 percent were distributed in Dega, Woina Dega and Kolla agroclimatic zones, respectively. The largest proportion of chicken population was thus reported from Woina Dega agroclimatic zone. In the region, 48 percent of the chickens are kept mainly for sale to generate income whereas 23, 16 and 13 percent of them are used for home consumption, cultural ceremonies and gifts, respectively. Eggs from Indigenous chickens are mainly used for generating income (45 percent), hatching chicks (35 percent), eaten at home (17 percent) and for other purposes (3 percent).

Phenotypic and morphological variations in qualitative traits

Description of phenotypic traits in indigenous chickens

Egg shell colour

A total of 1876 eggs were observed during field survey, of which 72.2 percent had creamy shell colour. The rest of the eggs had light brown (23.3 percent) and white (4.5 percent) shell colours. As presented in Table 1, the highest proportion of creamy egg shells were observed in Gedeo administrative zone (90.5 percent) followed by south Omo (88.9 percent), Keffa (82.1 percent) and Gurage (79.4 percent) administrative zones. The highest proportion of light brown egg shells was observed in Sheka (61.8 percent) and Wolayita (47.7 percent) administrative zones.

Earlobe colour

Of the investigated indigenous chicken populations, 46.4, 34.2 and 19.4 percent had red, white and yellow earlobe colours, respectively (Table 1). Indigenous chickens with the largest proportion of red earlobe colours (57–62 percent) was observed in Dawro, Hadiya and Sidama administrative zones with similar proportions; whereas the lowest in Gurage zone (29 percent). The indigenous chickens in Wolayita, Kembata-Tembaro and Sheka administrative zones as well as in those six special woredas showed red

Table 1. Phenotypic variations in egg shell and earlobe colours of indigenous chicken populations in different administrative zones (in %)

Administrative zones	Shell colour (*N*=1876)			Earlobe colour (*N*=3770)		
	Creamy	Light brown	White	White	Red	Yellow
Sidama	74.6	14.3	11.1	57.4	23.3	19.3
Wolayita	40.6	47.7	11.7	47.8	33.2	19.0
Gamo Gofa	60.4	35.1	4.52	38.3	42.3	19.4
Hadiya	61.4	25.7	12.9	60.1	24.1	15.8
Kembata-Tembaro	66.0	24.0	10.0	47.9	30.8	21.4
Selti	70.0	30.0	0.00	33.9	66.1	0.00
Gurage	79.4	8.84	11.8	29.4	56.4	14.2
South Omo	88.9	6.70	4.41	37.9	31.5	30.6
Gedeo	90.5	9.52	0.00	36.6	15.3	48.1
Dawro	72.7	21.8	5.50	62.7	37.3	0.00
Sheka	38.2	61.8	0.0	46.4	32.1	21.4
Bench Maji	73.5	26.5	0.00	43.1	55.9	0.98
Keffa	82.1	13.5	4.40	40.7	43.6	15.7
Special woredas[1]	79.0	19.5	1.50	50.1	32.6	17.4
Overall mean	72.2	23.3	4.50	46.4	34.2	19.4

[1]Mean values of six special woredas (Alaba, Amaro, Burji, Dirashe, Konso and Yem).

Table 2. Proportion of indigenous chicken populations showing different comb types across administrative zones (in %; *N*=3770)

Administrative zones	Single	Rose	Pea	Walnut	Duplex
Sidama	45.7	51.7	0.00	2.62	0.00
Gedeo	53.4	46.6	0.00	0.00	0.00
Wolayita	60.8	35.4	3.46	0.29	0.00
Gamo Gofa	58.2	26.0	15.5	0.19	0.00
South Omo	54.2	6.10	39.8	0.00	0.00
Hadiya	57.7	28.8	9.44	4.08	0.00
Kembata-Tembaro	55.3	24.9	19.8	0.00	0.00
Selti	29.7	35.6	33.9	0.00	0.00
Gurage	33.7	19.5	40.0	4.88	1.95
Dawro	53.0	24.0	23.0	0.00	0.00
Sheka	74.2	0.00	25.8	0.00	0.00
Bench Maji	65.7	24.3	10.0	0.00	0.00
Keffa	70.4	21.0	8.60	0.00	0.00
Special woredas[1]	60.6	25.5	13.4	0.00	0.50
Overall mean	55.0	28.5	15.2	1.12	0.19

[1]Mean values of six special woredas (Alaba, Amaro, Burji, Dirashe, Konso and Yem).

earlobes with similar proportions (46–48 percent). Likewise, the proportion of chickens with red earlobe colour in Keffa, Bench Maji, Gedeo, South Omo and Gamo Gofa administrative zones was more or less similar (37–41 percent). The highest proportion of earlobes with white colour was observed in chickens from Selti (66 percent) followed by Gurage and Bench Maji administrative zones with the same percentage values (56 percent).

Comb types

In general, 55 percent of the investigated chickens were single combed, followed by rose (28.5 percent) and pea (15.2 percent) combs. This figure shows that chickens found in rural areas of the region are mainly characterized by single and rose comb types, although the former appeared more frequently.

Of the total birds observed in Sheka, Keffa and Bench Maji administrative zones, about 74, 70 and 65 percent were single combed, respectively (Table 2). The distributions of single comb were similar across chickens found in Dawro, Kembata-Tebaro, Hadiya, south Omo, Gamo Gofa, Wolayita, Gedeo and Sidama administrative zones as well as special woredas, ranging from 45.7 to 60.8 percent. However, the proportion of rose comb in most studied zones appears to be variable, being highest in Sidama and Gedeo administrative zones. In Gurage and south Omo administrative zones, about 40 percent of the indigenous chickens possessed pea comb, whereas 5 and 2 percent of them had walnut and duplex combs, respectively.

Shank colour

The phenotypic variation in shank colour of investigated indigenous chicken populations is presented in Table 3. About 52.5, 29.1 and 14.7 percent of the chicken populations had a yellow, white and black shank colours, respectively, indicating yellow as the dominant shank colour. The proportion of chickens having yellow shanks is 73 and 70 percent for South Omo and Hadiya zones, respectively, which is comparatively higher than those found in other zones (Table 3). The distribution of yellow shank was similar among chicken populations from Bench Maji, Sheka, Gurage, Kembata-Tembaro, Gamo Gofa, Wolayita, Gedeo administrative zones and the six special woredas with the range of 49–58 percent. The largest proportions of chickens with white shank were observed in Selti, Kembata-Tembaro and Keffa administrative zones with similar value (about 42 percent).

Description of feather morphology and plumage colours

Feather morphology and distribution

Variations in basic feather morphology, distribution and plumage colour characteristics of the investigated indigenous chickens are presented in Table 4. Of the total indigenous chicken populations, 89 percent were normal whereas

Table 3. Phenotypic variations in shank colour of indigenous chicken populations from various administrative zones (%; *N*=3770)

Administrative zones	Yellow	White	Black	Grey-blue	Green
Sidama	41.3	28.8	25.7	4.22	0.00
Gedeo	57.6	25.8	16.6	0.00	0.00
Wolayita	49.3	30.2	14.2	4.55	1.34
Gamo Gofa	50.3	29.6	13.8	5.27	1.13
South Omo	72.7	20.8	6.49	0.00	0.00
Hadiya	69.7	15.5	10.8	2.33	1.75
Kembata-Tembaro	49.4	42.6	7.17	0.00	0.80
Selti	31.8	41.8	26.4	0.00	0.00
Gurage	50.3	38.6	1.31	9.80	0.00
Dawro	45.6	37.2	16.3	0.93	0.00
Sheka	53.6	28.6	7.14	3.57	7.14
Bench Maji	51.6	30.3	13.6	2.58	1.94
Keffa	42.2	42.8	12.6	2.41	0.00
Special woredas[1]	54.8	23.9	17.0	4.30	0.00
Overall mean	52.5	29.1	14.7	3.08	0.64

[1]Mean values of six special woredas (Alaba, Amaro, Burji, Dirashe, Konso and Yem).

Table 4. Variations in feather morphology, distribution and plumage colour of indigenous chicken populations in different administrative zones (*N*=3770)

Feather characteristics	Sidama	Gedeo	Wolayita	Gamo Gofa	South Omo	Hadiya	Kembeta-Tembaro	Selti	Gurage	Dawro	Sheka	Bench Maji	Keffa	Overall mean
Morphology														
Normal	94.3	89.1	100	80.0	85.4	59.5	100	100	100	75.2	78.6	95.8	100	89.1
Frizzle	5.70	10.9	0.00	7.60	9.90	15.7	0.00	0.00	0.00	24.8	21.4	4.20	0.00	7.70
Silky	0.00	0.00	0.00	12.4	4.72	24.8	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.21
Distribution														
Normal	86.2	86.0	87.7	63.6	94.2	88.1	89.3	80.0	84.4	73.3	86.7	74.0	87.9	83.2
Naked-neck	2.90	1.60	4.60	28.41	5.82	5.23	3.30	8.91	10.4	11.4	3.33	10.0	5.32	7.90
Crest	7.60	7.01	7.71	7.10	0.00	2.90	4.03	11.1	2.12	4.80	6.70	6.70	5.32	5.60
Shank and feet	3.33	5.40	0.00	0.40	0.00	1.01	0.70	0.00	2.60	6.70	0.00	5.30	0.80	2.00
Muff and beard	0.00	0.00	0.00	0.40	0.00	2.90	2.70	0.00	0.50	3.80	3.30	2.00	0.80	1.30
Plumage colour[1]														
Kei	46.4	24.8	36.3	32.4	49.2	30.2	67.6	22.8	18.7	29.5	37.0	47.9	33.7	36.6
Tikur	16.8	25.8	16.3	16.2	28.8	22.1	23.5	29.3	15.0	17.4	22.2	18.5	17.1	20.7
Netch	18.8	8.8	14.9	15.8	0.00	14.2	5.60	9.80	20.9	15.8	3.72	22.7	9.41	12.3
Gebsima	10.0	22.5	18.7	25.6	10.2	21.0	0.00	22.0	9.10	29.0	14.8	1.70	14.4	15.3
Kokima	5.30	4.60	4.10	6.60	11.9	5.20	0.00	16.3	11.2	7.40	22.2	0.00	14.9	8.40
Wosera	0.00	13.4	4.10	2.82	0.00	7.40	0.50	0.00	4.80	1.10	0.00	4.20	9.40	3.70
Zigrima	1.50	0.00	5.80	0.70	0.00	0.00	2.80	0.00	5.90	0.00	0.00	5.00	0.60	1.70
Zagolima	1.30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	14.4	0.00	0.00	0.00	0.60	1.30

Kei = Red plumage; Tikur = Black plumage; Netch = White plumage; Wosera = mixture of white and red with varying shades of multi-colours; Gebsima = mixtures of white and black with varying shades of multi-colours; Kokima = Grayish plumage, white or grayish strips on brown or reddish background; Zigrima = black and white spotted feathers on red background; Zagolima= white or red speckles on black background.
[1]Names of plumage colours are in Amharic, Official Working Language of Ethiopia.

Figure 2. Variations in plumage colour phenotypes in indigenous chicken populations found in southern region of Ethiopia. Upper left: Kei (red plumage colour); upper right: Gebsima (mixture of white and black plumage colours); lower left: Kokima (Grayish plumage colour); lower right: Wosera (mixture of white and red plumage colours).

the rest 7.7 and 3.2 percent had frizzle and silky feathers, respectively. The highest proportions of chickens with frizzle and silky feathers were reported in Dawro and Hadiya zones, respectively.

About 83.2 percent of the chicken populations had normal feather distribution followed by Naked-neck (7.9 percent), crested (5.6 percent, Figure 3), shank and feet (2.0 percent) and muff and beard (1.3 percent). As a means of adaptation to the hot climate, about 28 percent of the chicken populations in Gamo Gofa administrative zone were found to be Naked-neck. The distribution of Naked-neck chicken population in Gurage, Dawro and Bench Maji administrative zones showed similar proportions (10–11 percent). It would be worthwhile to note that indigenous chickens with Naked-neck gene were observed throughout all zones and five special woredas found in the southern region. Among the six special woredas, the highest proportions of Naked-neck chickens were found in Yem, Amaro (each 23 percent), followed by Alaba (5 percent), Konso (4.4 percent) and Dirashe (3.3 percent).

Plumage colour

About 37 percent of the investigated chickens in southern Ethiopia was predominantly characterized by Kei (Red) plumage colour (Figure 2), followed by Tikur (Black), Gebsima (mixtures of white and black, Figure 2) and Netch (White) plumage colours at a proportion of 20.7, 15.3 and 12.3 percent, respectively (Table 4). The remaining 8.4, 3.7, 1.7 and 1.3 percent of the chicken population had Kokima (Grayish plumage, Figure 2), Wosera (mixture of white and red, Figure 2), Zigrima (black and white spotted feathers on red background) and Zagolima (white or red speckles on black background) plumage colours.

As presented in Table 4, about 68 percent of chickens from Kembata-Tembaro administrative zone were characterized by Kei plumage colours. Similarly, chicken populations in south Omo, Bench Maji and Sidama administrative zones had Kei plumage at comparable proportions (46–49 percent). The proportion of Kei plumage in chicken populations of Dawro, Hadiya, Gamo Gofa, Keffa, Wolayita and Sheka administrative zones was comparable ranging from 30 to 37 percent as well. The highest chicken populations with Gebsima plumage colour was noted in Dawro zone at 29 percent, followed by Gamo Gofa, Gedeo, Selti and Hadiya administrative zones at the proportion of 25.6, 22.5, 22.2 and 21 percent, respectively. Chickens with Tikur plumage were observed in Selti, south Omo, Gedeo, Kembata-Tembaro, Sheka and Hadiya administrative zones ranging from 22 to 29 percent. The largest proportion of chickens with Kokima and Wosera plumages was found in Sheka and Gedeo administrative zones, respectively.

Variations in morphological traits in major agroclimatic zones

As presented in Table 5, yellow shank is the dominant colour in Kolla and Woina Dega agroclimatic zones, whereas white shank is most prevalent in Dega. Single comb was predominantly found in all agroclimatic zones appearing at comparable proportions. The highest proportion of

Figure 3. Some morphological variations in indigenous chicken populations found in the southern region of Ethiopia. Upper left: homozygous (NaNa) Naked-neck indigenous chickens; upper right: heterozygous (Nana+) Naked-neck indigenous chickens; lower left: Indigenous chicken with crested head; lower right: single and rose combed indigenous chickens with white earlobes.

duplex and walnut combs was only reported in the Woina Dega agroclimatic zone. Large proportions of chickens with red earlobes were found throughout all agroclimatic zones. The distribution of plumage colours across all agroclimatic zones was predominantly Kei with comparable pattern of occurrence. Chicken populations in Kolla and Dega agroclimatic zones were characterized by high proportion of Kei plumage followed by Tikur, Gebsima, Netch, Kokima and Wosera. In Dega, Gebsima is the second dominant plumage colour after Kei.

Variations in quantitative traits

Live body weight

The average body weight of adult males and females varied significantly ($p < 0.05$) among the investigated indigenous chickens (Table 6). Both male and female Naked-neck chickens were significantly ($p < 0.05$) heavier than the rest of the investigated indigenous chicken populations. Moreover, the body weight of Kei, Gebsima and Wosera chickens was comparatively higher than those of other indigenous chickens. The highest body weight was obtained from both sexes of Naked-neck and the lowest from Zigrima chickens.

Shank length and body weight shank ratio

As presented in Table 6, the shank lengths of Naked-neck and Wosera males were similar but significantly ($p < 0.05$) different for being longer than those of other indigenous chickens. In female chickens, the Naked-neck had the longest and Kokima the shortest shanks and were significantly different from those of other chickens. The body weight shank ratio (BW:SL) in Kei males was significantly ($p < 0.05$) larger than those of other chickens (Table 6). Kei, Kokima and Tikur females had similar BW:SL, which was significantly ($p < 0.05$) higher than those of other chickens. In general, the BW:SL of female chickens was significantly ($p < 0.05$) larger than that of male birds except for the Naked-neck chickens.

Discussion

Variations in phenotypic and morphological traits

Halima *et al.* (2007a) reported 7.1 flock sizes per HH, which is in good agreement with the current findings. Dana *et al.* (2010) reported an average indigenous chicken size of 3.5 per HH, which is twofold lower than the current study. An average flock size of 16 birds was reported in the central parts of Ethiopia (Tadelle, 2003), which is twofold higher than that found in the current study. In northwestern Ethiopia, Moges, Melesse and Dessie (2010) reported an average flock size of 13 birds per HH. Flock size in the region varies between seasons mainly because of the availability of feed, the occurrence of diseases, the presence of predators as well as the economic status of the owners reported by Melesse and Negesse (unpublished data) as a separate part of this study.

Table 5. Variations in basic phenotypic and morphological traits in different agroclimatic zones (in %)

Traits	Kolla	Woina Dega	Dega
Shank colour			
Yellow	44.9	54.2	39.7
White	38.2	38.9	47.9
Black	13.9	12.1	9.52
Blue	3.10	4.02	1.75
Green	0.25	0.80	1.11
Comb types			
Single	55.1	48.4	54.7
Rose	35.0	28.2	31.8
Pea	9.92	22.5	13.5
Walnut	–	0.59	–
Duplex	–	0.30	–
Earlobe colour			
Red	42.2	46.2	39.0
White	34.9	30.7	30.4
Creamy	22.7	23.1	30.6
Plumage colour[1]			
Kei	35.4	40.8	39.5
Tikur	23.3	22.3	18.4
Gebsima	18.7	16.3	22.0
Netch	17.6	16.3	14.9
Kokima	11.4	5.95	8.87
Wosera	5.04	4.34	5.14
Zagolima	–	1.89	–
Zigrima	2.96	1.50	2.30

Kolla = lowland below 1500 m; Woina Dega= midland between 1500–2500 m and Dega = highland above 2500 m a.s.l.
Kei = Red plumage; Tikur = Black plumage; Netch = White plumage; Wosera = mixture of white and red with varying shades of multi-colours; Gebsima= mixtures of white and black with varying shades of multi-colours; Kokima = Grayish plumage, white or grayish strips on brown or reddish background; Zigrima = black and white spotted feathers on red background; Zagolima= white or red speckles on black background.
[1]Names of plumage colours are in Amharic, Official Working Language of Ethiopia.

According to Ssewannyana *et al.* (2008), 48 and 47 percent of the shell of eggs collected from indigenous chickens in Uganda were light brown and white colours, respectively, which is higher than those observed in the present study. Shell colour is primarily a breed characteristic, although there is often variation among individual hens in a particular flock even when all are of the same breed and variety. Egg shells of commercial breeds of chickens are white or brown. Breeds with white earlobes ordinarily lay white eggs, whereas breeds with red earlobes ordinarily lay brown eggs (Jacob, Miles and Mather, 2009).

According to Dana *et al.* (2010), the proportion of indigenous chickens showing white earlobe was 40 percent, which is slightly lower than those reported in the current study. The same authors reported a large proportion of chickens with red earlobes, which is higher than those found in the current study. In agreement with the present findings, Duguma (2006) reported the predominance of white earlobe in indigenous chickens from south-western, western and eastern parts of Ethiopia. In Nigeria, Egahi *et al.* (2010) reported a high proportion of indigenous chickens (about 73 percent) with white earlobes, which is higher than that observed in the current study. According to Ssewannyana *et al.* (2008) the proportion of white and red earlobes in indigenous chickens in Uganda was almost the same (48 and 47 percent). It is apparent that earlobe colour is a breed-specific trait, although it could be affected by nutritional status of the birds. All standard chicken breeds that originated from Mediterranean regions (such as Leghorn or Ancona) exclusively possess white earlobes, whereas other breeds such as Rhode Island Red, New Hampshire. have earlobes with red colour.

Indigenous chicken populations possessing a high proportion of single comb were reported in other countries (Mcainsh *et al.*, 2004; Badubi, Rakereng and Marumo, 2006; Egahi *et al.*, 2010). According to Badubi, Rakereng and Marumo (2006), about 90 percent of the indigenous chickens in Botswana were single combed, whereas very low proportion of rose (4.9 percent) and pea (1 percent) combs. Moges, Melesse and Dessie (2010) reported that single and rose combs are the most

Table 6. Adult live body weight and shank length of indigenous chicken populations (mean ± SD; *N*=2340)

Plumage colour[1]	Body weight (g)		Shank length (mm)		Body shank ratio (g/mm)	
	Male	Female	Male	Female	Male	Female
Kei	1510 ± 130^{b}	1204 ± 101^{b}	98.3 ± 13.4^{c}	73.7 ± 9.3^{d}	15.6 ± 2.33^{a}	16.6 ± 2.7^{a}
Tikur	1392 ± 119^{d}	1124 ± 97^{c}	98.1 ± 11.7^{c}	70.3 ± 8.1^{e}	14.4 ± 1.92^{cd}	16.2 ± 2.21^{a}
Gebsima	1451 ± 128^{c}	1149 ± 93^{c}	106 ± 10.8^{b}	76.3 ± 8.7^{c}	13.9 ± 1.89^{cd}	15.3 ± 2.31^{b}
Netch	1373 ± 106^{d}	1072 ± 82^{d}	105 ± 11.0^{b}	76.5 ± 9.7^{c}	13.3 ± 1.78^{ef}	14.2 ± 1.79^{d}
Kokima	1233 ± 102^{e}	1040 ± 100^{e}	90.9 ± 10.8^{d}	63.9 ± 8.6^{g}	$13.8 \pm 2.1d^{e}$	16.6 ± 2.87^{a}
Wosera	1458 ± 93^{c}	1184 ± 77^{b}	113 ± 11.9^{a}	83.8 ± 10.5^{b}	13.1 ± 1.84^{f}	14.4 ± 2.01^{d}
Zagolima	1254 ± 97^{e}	1011 ± 95^{f}	97.6 ± 6.0^{c}	70.3 ± 6.4^{e}	12.9 ± 1.23^{f}	14.5 ± 1.64^{cd}
Zigrima	1219 ± 81^{e}	1000 ± 83^{f}	93.7 ± 9.9^{d}	67.1 ± 7.6^{f}	13.2 ± 1.83^{f}	$15.1 \pm 2.42b^{c}$
Naked neck	1717 ± 137^{a}	1349 ± 116^{a}	115 ± 9.1^{a}	89.4 ± 7.9^{a}	15.0 ± 1.67^{b}	15.2 ± 1.84^{b}
Total mean	1427 ± 18^{A}	1144 ± 14^{B}	102 ± 13.5^{A}	75.3 ± 11^{B}	14.1 ± 2.10^{B}	15.5 ± 2.43^{A}

Means within a column between indigenous chickens with different superscript letters are significantly ($p < 0.05$) different
Kei = Red plumage; Tikur = Black plumage; Netch = White plumage; Wosera = mixture of white and red with varying shades of multi-colours; Gebsima = mixtures of white and black with varying shades of multi-colours; Kokima = Grayish plumage, white or grayish strips on brown or reddish background; Zigrima = black and white spotted feathers on red background; Zagolima = white or red speckles on black background.
[1]Names of plumage colours are in Amharic, Official Working Language of Ethiopia.

prevalent comb types in north-western Ethiopia. In contrast, Halima *et al.* (2007b) and Dana *et al.* (2010) reported pea comb as a predominant type in other parts of Ethiopia. These discrepancies might have been caused by confusions that may arise between rose and pea combs (Dana *et al.*, 2010). Pea comb is a breed characteristic found in Cornish, Brahmas, Ameraucanas, Buckeyes, Cubalayas and Sumatras and is sometimes called a triple comb (Somes, 2003). Rose and single are comb types most commonly found in chickens (Bell, 2002). When rose and pea combed birds are crossed, the comb is intermediate and given the name walnut comb. Rose comb and pea comb are dominant to single comb. Thus, in chicken populations with the highest proportion of pea comb, the occurrence probability of single comb would be very low. Comb type is the result of gene interaction, but comb size is associated with gonadal development and the intensity of light, either natural or artificial (Bell, 2002).

Dana *et al.* (2010) and Halima *et al.* (2007b) reported yellow shank as the most prevalent trait in indigenous chicken populations found in other parts of Ethiopia, which agrees with the current findings. According to Ssewannyana *et al.* (2008), 42 percent of the indigenous chickens in Uganda had yellow shank, which is comparable to the present findings. Moreover, Dana *et al.* (2010) reported 28 percent of indigenous chickens with white shanks, which is in line with the present findings (29.1 percent). However, Faruque *et al.* (2010) reported white shank (35 percent) as the most predominant colour in Bangladesh native chickens. Moreover, 42.2 percent of Nigerian indigenous chickens had a black shank (Egahi *et al.*, 2010). The shanks and most of the feet are covered with scales of various colours (Bell, 2002). Yellow is due to dietary carotenoid pigments in the epidermis when melanic pigment is absent. Varying shades of black are the result of melanic pigment in the dermis and epidermis (Bell, 2002). When there is black pigment in dermis and yellow in epidermis, the shanks have greenish appearance. In the complete absence of both of these pigments, the shanks are white.

Melesse and Negesse (unpublished data) observed shortage of scavangable feed resources in the highland agroclimatic zone of the region, which might be a possible explanation for the predominance of white shank in this agroclimatic zone. Dana *et al.* (2010) reported high proportion of white skin colour in those chickens from highland regions.

Fizzle gene is incompletely dominant autosomal gene, which causes the contour feathers to curve outward away from the body (Somes, 2003). It also causes a reduction in feather weight at slaughter (up to 40 percent). This gene will thus reduce the insulating properties of the feather cover because of reduced feather weight and makes it easier for the bird to dissipate heat effectively from the body by means of convection, making them suitable in hot climates (Horst, 1989).

According to reports of Ssewannyana *et al.* (2008), 75 percent of indigenous chickens in Uganda were normal feathered followed by those with crests (12 percent), Naked-neck (9 percent) and feathered shanks (4 percent), which are comparable with the results of this study. The Naked-neck gene is described as one of the major genes in indigenous chickens of the tropics that possess desirable effects on heat tolerance and adult fitness (Melesse, 2000; Maak *et al.*, 2003; Melesse, Maak and vonLengerken, 2005). The homozygote state of Naked-neck gene reduces feather coverage by about 15–20 percent in heterozygous and by 30–40 percent in homozygous chickens (Yunis and Cahaner, 1999). Reduced feather coverage should improve and enhance heat dissipation and consequently alleviate the effects of heat on chickens reared in hot climates. In addition, reduced feathering saves on feather proteins, which may be used for egg or meat production (Ajang *et al.*, 1993). The total proportion of chickens carrying the Naked-neck gene in the populations that we studied was higher than those reported in other parts of Ethiopia (2 percent; Dana *et al.*, 2010) and in Botswana (3.6 percent; Badubi, Rakereng and Marumo, 2006). This major difference is expected as southern part of Ethiopia has been long known by the existence of Naked-neck chicken as native chicken population (Teketel, 1986; Melesse, 2000).

The plumage colours found in the current study are in agreement with previous reports by Missohou, Sow and Ngwe-Assoumou (1998) for indigenous chicken populations in Senegal. Duguma (2006) also found similar plumage colours in indigenous chickens from Horro, Tepi and Jarso parts of Ethiopia. In north-western Ethiopia, Kibret (2008) reported 39 percent of the chicken populations having Kei plumage, which is comparable with the current findings. Moreover, in line with the present study, Dana *et al.* (2010) reported Kei as the most prevalent plumage colour in those chicken populations from southern part of Ethiopia (Konso and Sheka areas), Oromia and Benshangul-Gumuz regions. In contrast to the present finding, 25.5 percent of indigenous chickens in the northwest parts of Ethiopia had Netch plumage colour followed by a grayish mixture (22.2 percent) and Kei (16.4 percent) (Halima *et al.*, 2007b). According to Moges, Melesse and Dessie (2010), 54 percent of chicken populations investigated in north-western Ethiopia had Kei plumage, which is higher than the current findings.

In the literature, large variations in plumage colours across regions were found, which might be due to geographical isolation as well as periods of natural and to some extent, artificial selections. Furthermore, these variations could be due to limited exchange or transport of local chickens over long distances as it is commonly observed in large animals. Chickens and their products are mostly sold in the nearby markets for HH consumption purposes. Moreover, most farmers in the rural community produce replacement chickens from their own flocks. In the worst

case, they may buy chickens from nearby markets if needed for replacement purposes.

Feather colours and feather patterns are the result of genetic differences (feather colour is sex-linked) and the presence of gonadotropic hormones (Bell, 2002). However, most of the important feather colours in fowl result from the presence of pigments (Stevens, 1991). The most important pigments are the melanins, which are the principal black and red pigments in feathers.

Based on field and market observations as well as interview with village community, chickens with Gebsima plumage were further categorized as black Gebsima (white spots on black background) and white Gebsima (black spots on white background). Similarly, chickens with Wosera plumage were classified as red Wosera (white spots on red background) and white Wosera (red spots on white background). Contrary to the present findings, Wosera plumage elsewhere in Ethiopia was described as a mixture of black and white whereas Gebsima as a grayish mixture (Tadelle, 2003). Dana *et al.* (2010) described the Gebsima chickens with wheaten strips on black background. The description of Zagolima and Teterima plumage colours given by Dana *et al.* (2010) was somehow similar to those of the present study. However, the plumage colour description of Teterima is not reported in southern Ethiopia.

Variations in quantitative traits

The body weight ranges for males (1.22–1.72 kg) and females (1.0–1.35 kg) in the current study were in close agreement with those reported by Dana *et al.* (2010) under field conditions. The adult body weight of male (2.1 kg) and female (1.4 kg) indigenous chickens in Uganda reported by Ssewannyana *et al.* (2008) was higher than observed in the present study. As expected, the mature male chickens were significantly heavier than females and are in line with the reports of Halima *et al.* (2007b) and Dana *et al.* (2010). Body weights of Naked-neck females in the current study is in line with the findings of Melesse 2000 and Melesse, Maak and vonLengerken (2005) on the same type of adult female birds under intensive management (1.35 vs. 1.27 kg). The first work on the growth performance of Kei, Netch, Tikur, Gebsima, Kokima and Naked-neck chicken was reported by Teketel (1986). Among these indigenous chickens, the Naked-neck chickens were found to be better in body weight than those of other indigenous chickens, which is in a good agreement with the present findings.

This Naked-neck gene reduces feather coverage around the neck region (Figure 3), which facilitates body heat dissipation during hot weather (Deeb and Cahaner, 2001). Thus, those chickens carrying this gene are likely more beneficial in the lowland areas of the country where the heat stress situation could be a major problem for small-scale poultry production. Nevertheless, as illustrated in Figure 3, it appears that there is a high possibility of interbreeding with other indigenous chickens resulting in heterogeneous type of Naked-neck gene. Moreover, interviewed HHs reported that consumers in urban markets have neglected live chickens carrying this gene because of cultural reasons that are possibly linked with the absence of feather coverage around the neck region. Dana *et al.* (2010) also reported similar concerns from interviewed farmers. It is thus apparent that the future of the Naked-neck gene is at risk unless appropriate measures are taken towards its conservation at its habitat (*in situ*).

The range of shank length in males (9.1–11.5 cm) in the present study is within the range to those reported by Halima *et al.* (2007a) for indigenous male chickens (9.5–11.3) reared under intensive management. The shank length reported by Msoffe *et al.* (2001) for adult scavenging indigenous chickens in Tanzania was much higher than those observed in the present study. The shank length of indigenous males in Botswana was 85 mm (Badubi, Rakereng and Marumo, 2006), which was shorter than that observed in the present study (85 vs. 102 mm). The short shank length found in female than male chickens is in line with previous reports by Halima *et al.* (2007b) and Dana *et al.* (2010). The average shank length of females in the present study is comparable to those of indigenous chickens (70 vs. 75 mm) from Botswana (Badubi, Rakereng and Marumo, 2006). Shank length is regarded as a good indicator of skeletal development, which is related to the amount of meat a chicken can carry. Thus, the present study suggests that the Naked-neck might possess a better bone strength, which could be associated with its active walking potential to cover longer distances in search of feed. In naturally hot climates, the Naked-neck broiler chickens exhibited greater weight gain compared with their fully feathered counterparts (Yalcin *et al.*, 1997).

The body weight shank ratio is an indicator of degree of fleshing in relation to body size. It usually increases with body size (Renema *et al.*, 2007). The current study suggests that the indigenous chickens with Kei plumage might possess a useful genetic potential for table meat production under scavenging feed resource-based production system. However, the Naked-neck chickens, which showed better body weight and shank length, were inferior in their fleshing capacity in relation to their body size, suggesting their suitability for egg production purpose.

Conclusions

Based on field and market appraisals as well as interviews with smallholder HHs, single comb, yellow shank and red earlobes were the predominant phenotypic traits of indigenous chickens across all agroclimatic zones. The most prevalent plumage colour in all agroclimatic zones was Kei occurring at comparable proportions. The highest adult body weight was obtained from Naked-neck,

followed by Kei, Gebsima and Wosera chickens. Similarly, Naked-neck and Wosera chickens had the longest shank whereas the body weight shank ratio in Kei males was larger than those of other indigenous chickens. The population of indigenous chickens studied showed heterogeneity in most morphological traits considered. Thus, an in-depth molecular evaluation using genetic markers should be undertaken to substantiate the level of genetic differentiation and relationships among indigenous chicken populations.

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Preliminary analysis of microsatellite-based genetic diversity of goats in southern Nigeria

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Summary
To better understand natural genetic variation in indigenous livestock resources, as well as formulate conservation policies, better genetic characterization is required to balance the competing needs of genetic improvement and conservation of native germplasm, primarily in rural agricultural systems in developing countries. Genetic diversity of goats in southern Nigeria was assessed using 295 indigenous goats with ten microsatellite DNA markers. The breeds are West African Dwarf (WAD), Red Sokoto (RS) and Sahel (SA) sampled from farms, market places and rural homesteads. The mean expected heterozygosity (H_E) ranged from 0.608 to 0.784 in two sub-populations of WAD goats. Deviations from Hardy–Weinberg equilibrium (HWE) were statistically significant ($p < 0.05$) indicating that these populations are under various forces stemming from the management choices of rural dwellers. Polymorphic information content of these markers averaged 0.803 and mean G_{ST} index was 0.176. The measure of genetic distance between pairs of breeds indicated that the lowest distance was between WAD and RS (0.268) and the highest distance was between WAD and SA (0.662) goats, respectively. The estimated dendogram clustered these Nigerian goats into nine sub-populations and two major genetic groups. The study suggests that indigenous goat populations in southern Nigeria may be collapsed from three breeds into two distinct genetic groups, possibly due to extensive cross-breeding and gene flow between them, which are symptomatic of uncontrolled crossing across much of the country.

Keywords: *DNA, genetic diversity, goats, microsatellite, Nigeria*

Résumé
Afin de mieux comprendre la variation génétique naturelle des ressources des animaux d'élevage indigènes et pour élaborer des politiques de conservation, il est nécessaire d'améliorer la caractérisation génétique qui équilibre les besoins opposés de l'amélioration génétique et de la conservation du matériel génétique local, en particulier dans les systèmes ruraux et agricoles des pays en développement. On a évalué la diversité génétique des chèvres dans le sud du Nigéria en utilisant 295 chèvres indigènes avec 10 marqueurs microsatellites d'ADN. Les races, dont les échantillons ont été saisis dans les exploitations agricoles, dans les marchés et dans les fermes familiales, étaient la West African Dwarf, la Red Sokoto et la Sahel. L'hétérozygotie moyenne prévue dans deux sous-populations de chèvres West African Dwarf variait entre 0,608 et 0,784. Les écarts par rapport à l'équilibre de Hardy-Weinberg ont été significatifs du point de vue statistique ($p < 0.05$), ce qui indique que ces populations subissent des pressions différentes selon les choix de gestion des habitants des zones rurales. Le contenu d'informations polymorphiques de ces marqueurs a été en moyenne de 0,803 et l'index de GST moyen a été de 0,176. La mesure de la distance génétique entre deux races a indiqué respectivement la distance la plus faible entre les chèvres West African Dwarf et Red Sokoto (0,268) et la plus élevée entre les chèvres West African Dwarf et Sahel (0,662). Le dendrogramme estimé a regroupé ces chèvres nigériennes dans neuf sous-populations et dans deux groupes génétiques majeurs. L'étude suggère que les populations de chèvres indigènes dans le sud du Nigéria proviennent probablement de trois races qui se sont assemblées dans deux groupes génétiques distincts, probablement en raison d'importants croisements et flux de gènes entre ces races, qui révèlent la présence de croisements non maîtrisés dans une grande partie du pays.

Mots-clés: *ADN, diversité génétique, chèvres, microsatellite, Nigéria*

Resumen
Análisis preliminar de microsatélites basados en la diversidad genética caprina del sur de Nigeria. Para comprender mejor la variación genética natural en los recursos ganaderos indígenas, así como formular las políticas de conservación, es necesario llevar a cabo una mejor caracterización genética para equilibrar las necesidades competitivas de la mejora genética y conservación de germoplasma nativo, principalmente en los sistemas agrícolas de los países en desarrollo. La diversidad genética de las cabras del sur de Nigeria se evaluó utilizando 295 cabras indígenas con 10 marcadores de microsatélites de ADN. Las razas muestreadas en las explotaciones, en los mercados y en las haciendas fueron la West African Dwarf (WAD), la Red Sokoto (RS) y la Sahel (SA). La heterocigosidad

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media esperada (HE) varió desde 0,608 hasta 0,784 en dos subpoblaciones de cabras WAD. Las desviaciones del equilibrio Hardy-Weinberg (HWE) fueron estadísticamente significativas ($p < 0,05$), indicando que estas poblaciones se encuentran bajo diversas fuerzas relacionadas con la gestión de la población rural. El contenido de información polimórfica de estos marcadores fue de un promedio de 0,803 y el índice medio GST fue 0,176. La medida de la distancia genética entre los pares de razas indicó que la menor distancia se encuentra entre los animales WAD y los RS (0.268) y la mayor distancia entre las cabras WAD y las cabras SA (0,662), respectivamente. El dendograma agrupó estas cabras de Nigeria en nueve subpoblaciones y dos grupos genéticos más importantes. El estudio pone de manifiesto que las poblaciones caprinas indígenas del sur de Nigeria podrían venirse abajo como tales tres razas, pasando a formarse dos grupos genéticos diferentes, posiblemente debido al cruzamiento y al flujo genético entre ellas, por el cruzamiento con controlado que está teniendo lugar en.

Palabras clave: *AND, diversidad genética, cabras, microsatélite, Nigeria*

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Introduction

Goats constitute the largest group of small ruminant livestock in Nigeria totalling about 53.8 million and also constituting 6.2 percent of the World's goat population (FAOSTAT, 2011). Surveys have shown that up to 85 percent of rural households, poor farmers and small-time business people of all age groups and sexes keep them (FDLPCS, 2007). The ability of goats to tolerate harsh climates, the presence of trypanotolerance in some breeds (Salako, 2004), suitability to traditional systems on account of small size, short generation interval (Abdul-Aziz, 2010) and ability to thrive on poor quality diets provided by scarce grazing on marginal lands (Adedeji *et al.*, 2011) all combine to make small ruminants strategic to increasing livestock productivity in rural agricultural systems (Adebambo *et al.*, 2004; Adedeji *et al.*, 2011). Despite these advantages, little attention had been paid to the genetic characterization and possible improvement of small ruminants in Nigeria. Several reports on performance characteristics have been published by Odubote and Akinokun (1992), Odubote (1994*a*, *b*), Ebozoje and Ngere (1995), Ozoje (1998) and Imumorin, Ologun and Oyeyemi (1999). While earlier reports attempted to study genetic variation of haemoglobin (Buvanendran *et al.*, 1981; Imumorin, Ologun and Oyeyemi, 1999) and transferrin types in goats (Moruppa, 1985), a very recent report reported genetic distance of 0.39 between Red Sokoto (RS) and West African Dwarf (WAD) goats in southwestern Nigeria using microsatellite DNA markers using a relatively small sample size of 138 animals (Adebambo *et al.*, 2011).

Genetic improvement of indigenous breeds of livestock is very valuable because of high adaptability to harsh environmental conditions of nutrition, climate and disease compared with exotic breeds (Fitzhugh, Ehui and Lahlou-Kassi, 1992). According to Groeneveld *et al.* (2010) many breeds of livestock may become lost germplasm in many third world countries due to crossing with exotics, which in addition to uncontrolled breeding in extensive management systems pose a great risk for the loss of valuable genes. To better understand natural genetic variation in native goats as well as formulate conservation policies, better genetic characterization is required to balance the competing needs of genetic improvement and conservation of native germplasm to preserve the age-long relationship between native livestock and dwellers in rural agricultural systems (Groeneveld *et al.*, 2010). However, there is very little baseline information on the extent of natural genetic variation in Nigerian goats. This project was therefore aimed at assessing genetic diversity of indigenous Nigerian goats in southern Nigeria using ten microsatellite DNA markers in a sample size larger than Adebambo *et al.* (2011) in three extant goat breeds. The results of this regional study provide additional preliminary data to support more extensive molecular characterization of small ruminants in Nigeria covering the entire country.

Materials and methods

Animals and DNA extraction

A total of 295 samples made up of 128 WAD (Figure 1), 131 RS (Figure 2) and 36 Sahel (SA; Figure 3) goats were sampled across southern Nigeria from Ogun, Oyo, Delta and Rivers States between latitude 04°48′N and 07°10′N, longitude 03°52′E and 07°92′E at an elevation of between 115 and 122 m above sea level. About 10 ml of whole blood was collected from the jugular vein into vacutainer tubes with Ethylenediaminetetraacetic acid (EDTA) and stored at 4 °C and transported to the laboratory. Genomic DNA was extracted using MasterPure DNA extraction kit (Epicenter Biotechnol- ogies, Madison, WI, USA) according to the manufacturer's instructions. The research protocol was approved by the Institutional Animal Care and Use Committee of the University of Agriculture, Abeokuta.

Microsatellite markers and genotyping

Ten microsatellites used in this study were randomly chosen from the FAO-recommended list (http://dad.fao.org; Hoffmann *et al.*, 2004) and are presented in Table 1.

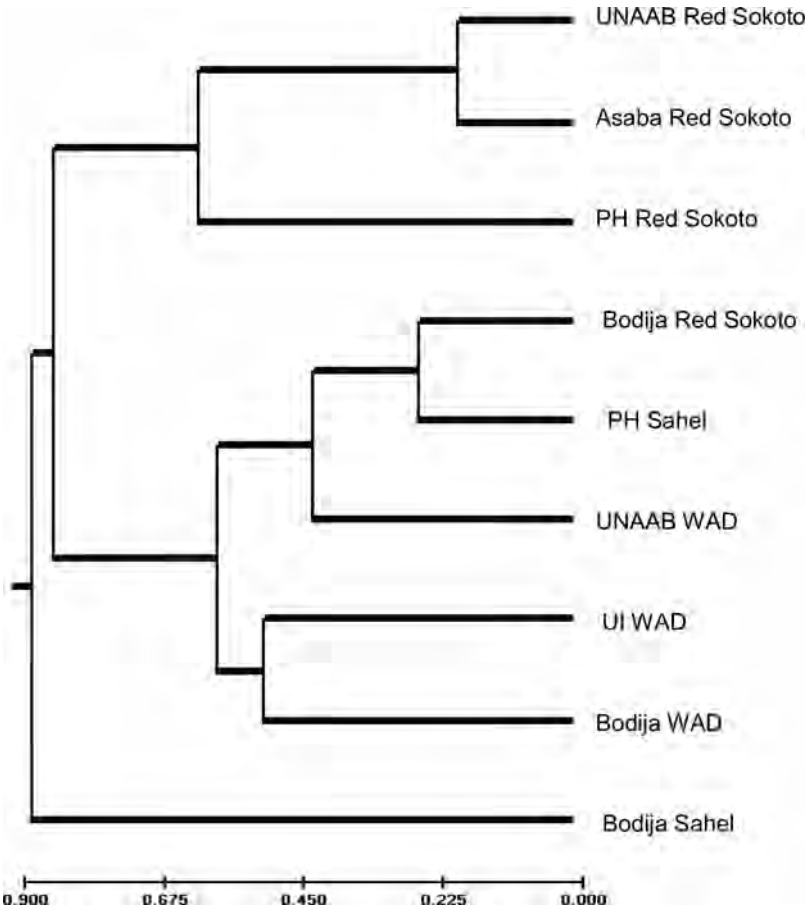

Figure 1. West African Dwarf goat.

PCR amplification was carried out in a 25 µl of total volume reaction mixture containing approximately 50 ng of goat genomic DNA, 2.5 mM dNTPs, 2.5 µl of 10 × PCR buffer, 5 µl of red juice dye, 11.5 µl of deionized water, 1 µl of each of the appropriately fluorescently labelled forward and reverse primers, 0.5 µl of Taq polymerase (1:10 dilution in H_2O of stock). The cycling conditions were: initial denaturation step 94 °C for 3 minutes, 35 cycles of denaturation at 94 °C for 30 seconds, 55, 57 or 60 °C for 30 seconds (varied with annealing

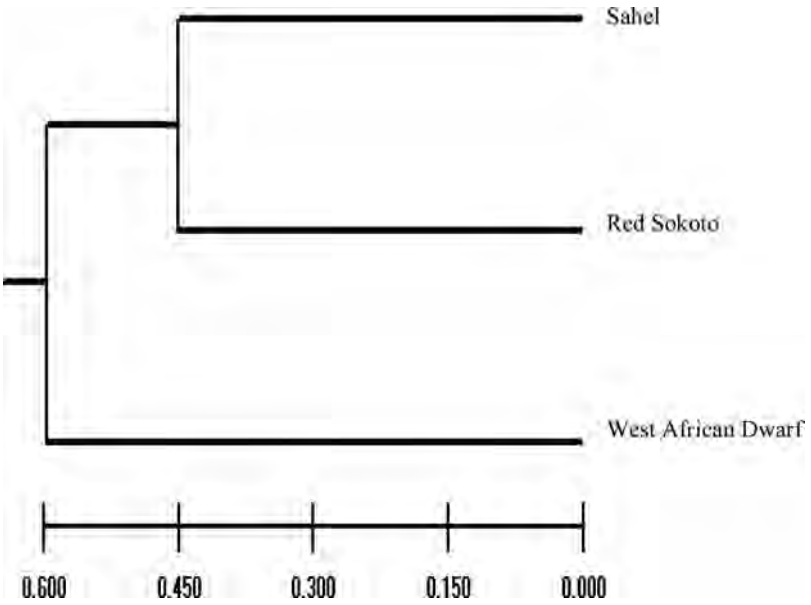

Figure 2. Red Sokoto goat.

Figure 3. Sahel goat.

temperature of markers) and 72 °C for 45 seconds, followed by a final extension step at 72 °C for 4 minutes. The PCR products were multiplexed and genotyped using an Applied Biosystems 3100 Genetic Analyzer and bands were analysed using Peakscanner® software (Applied Biosystems, Foster City, CA, USA).

Statistical analysis

Polymorphism information content (PIC) for each microsatellite marker was calculated using CERVUS software (Marshall, 1998). Population statistics were estimated using Tools for Population Genetic Analyses (TFPGA) software version 1.3 (Miller, 1997) and FSTAT version 2.9.3 (Goudet, 2001). Analysis of molecular variance (AMOVA) was done using GenAlEx 6.3 (Peakall and Smouse, 2006). The analyses included allele frequencies, expected heterozygosity (H_E), observed heterozygosity (H_O) and Hardy–Weinberg equilibrium (HWE). For the analysis of genetic differentiation between populations, Wright's fixation indices were computed by bootstrapping with a 95% confidence interval based on 1 000 replicates. Additionally, *F*-statistics covering F_{IS}, consanguinity or loss in heterozygosity within population; F_{ST}, measure of differentiation among populations, and F_{IT} global loss in heterozygosity and exact test of Hardy–Weinberg proportion for multiple alleles (Guo and Thompson, 1992) were estimated using the Markov Chain procedure (10 batches, 1 000 iterations, 1 000 de-memorization steps) implemented in *F*-STAT version 2.9.3 (Goudet, 2001). Both genetic distance (D_A) estimated according to the method of Nei (1978) and the unweighted pair group method with arithmetic mean (UPGMA) for dendogram construction were carried out using TFPGA version 1.3 (Miller, 1997).

Results

Characteristics of microsatellite DNA markers

A detailed description of the ten microsatellite markers used in this study is presented in Table 1. A total of 140 alleles were generated with the number of alleles per locus ranging from 8 for ETH225 and SRCRSP3 to 26 for SRCRSP6. Table 2 summarizes details of gene diversity indicated by H_E which ranged from 0.599 for ETH225 to 0.921 for SRCRSP6. The PIC ranged from 0.521 for ETH225 to 0.914 for SRCRSP6. The F_{IT} values ranged from −0.097 for IDVGA7 to 0.888 for SRCRSP3. The F_{ST} values ranged from 0.048 for ETH225 to 0.191 for SRCRSP3. Fixation index (F_{IS}) values ranged from −0.003 for SRCRSP 6 to 0.861 for SRCRSP3. Markers ETH225, TGLA40, ILSTS5, SRCRSP10 and IDVGA7 had negative F_{IS} values, while SRCRSP5, SRCRSP3, SRCRSP6 SRCRSP9 and BM6526 had positive F_{IS} values. In our data, G_{ST} which indicates that genetic

Table 1. Characteristics of microsatellite markers used in this study.

Sl. No.	Locus	Sequences (F and R)	Allele No.	Size range	Annealing temperature (°C)
1	ETH225	GATCACCTTGCCCACTATTTCCT ACATGACAGCCAGCTGCTACT	8	104–154	57
2	ILSTS5	GGAAGCAATGAAATCTATAGCC TGTTCTGTGAGTTTGTAAGC	10	104–116	60
3	TGLA40	GCTTCTCTGCCAACTAATATTATCC CACCAGGTAAGCCCCTTATATATGT	13	104–116	55
4	SRCRSP5	GGACTCTACCAACTGAGCTACAAC TGAAATGAAGCTAAAGCAATG	17	281–308	57
5	SRCRSP3	CGGGGATCTGTTCTATGAAC TGATTAGCTGGCTGAATGTC	8	302–308	57
6	BM6526	CATGCCAAACAATATCCAGC TGAAGGTAGAGAGCAAGCAGC	11	281–308	57
7	SRCRSP10	ACCAGTTTGAGTATCTTGCTTGG ACGAACTTTATTGGACZTGCTGG	17	104–304	55
8	SRCRSP9	AGAGGATCTGGAAATGGAATC GCACTCTTTTCAGCCCTAATG	13	148–304	60
9	IDVGA7	GGGTGGGCTTCATTTCTATG CAGCCACTGTCTCCTCCCAC	17	103–149	60
10	SRCRSP6	CATAGTTCATTCACAATATGGCA CATGGAGTCACAAAGAGTTGAA	26	149–305	55

Table 2. Heterozygosity, polymorphic information content, *F*-statistics and gene flow.

Locus	H_E	H_O	PIC	F_{IT}	F_{ST}	F_{IS}	G_{ST}	Nm*
ETH225	0.599	0.970	0.521	−0.626	0.048	−0.709	0.626	18.901
TGLA40	0.733	0.939	0.685	−0.268	0.077	−0.374	0.761	3.018
ILSTS5	0.826	0.939	0.802	−0.129	0.062	−0.204	0.084	4.264
SRCRSP5	0.899	0.759	0.890	0.170	0.079	0.098	0.141	2.954
SRCRSP3	0.832	0.098	0.812	0.888	0.191	0.861	0.367	2.287
BM6526	0.828	0.285	0.809	0.663	0.172	0.593	0.261	2.296
SRCRSP10	0.089	0.817	0.884	0.097	0.105	−0.009	0.184	3.451
SRCRSP9	0.860	0.600	0.844	0.339	0.150	0.222	0.189	2.284
IDVGA7	0.884	0.946	0.871	−0.097	0.092	−0.208	0.144	2.897
SRCRSP6	0.921	0.848	0.914	0.104	0.102	0.003	0.168	5.529
Mean over all loci	0.747	0.720	0.803	0.148	0.111	0.042	0.176	3.208
Jack knifing (all loci)				0.151 ± 0.13	0.111 ± 0.02	0.043 ± 0.13		
Bootstrapping (95% CI)				−0.09 ± 0.39	0.08 ± 0.14	−0.19 ± 0.29		
Bootstrapping (99% CI)				−0.16 ± 0.47	0.08 ± 0.15	−0.26 ± 0.37		

*Nm, gene flow estimated from $F_{st} = 0.25(1 - F_{st})/F_{st}$.
H_E, expected heterozygosity; H_O, observed heterozygosity; PIC, polymorphic information content; F_{IT}, amount of inbreeding like effect within entire population; F_{ST}, amount of variations due to differentiation between subpopulations; F_{IS}, amount of inbreeding like effect among individuals within subpopulations; G_{ST}, coefficient of gene differentiation; CI, confidence interval.

differentiation ranged from 0.144 for IDVGA7 to 0.761 for TGLA40. Analysis of markers' usefulness showed that markers TGLA40, ETH225, SRCRSP3, BM 6526, SRCRSP9 and SRCRSP10 had G_{ST} values higher than the mean (Table 2). On the other hand, markers ILSTS5, IDVGA7 and SRCRSP6 had G_{ST} values that were lower than the mean (0.084, 0.144 and 0.168, respectively), while gene flow (N_m) ranged from 2.284 for SRCRSP9 to 18.901 for ETH225.

Population structure and genetic diversity

H_E within breeds is described locus by locus in Table 3. Table 4 shows average genetic diversity among breeds by location, while Table 5 shows the estimated analysis of molecular variation for within and among populations sampled. Results showed that two sub-populations of RS from Abeokuta and Asaba are more related (0.833) than all others, while genetic diversity was greatest between populations of WAD from Abeokuta and SA from Ibadan (1.286). Genetic distance matrix of the three different breeds (Tables 6 and 7) showed that WAD goats shared about 52% similarity and about 66% diversity with SA goats, and about 64% similarity and 44% diversity from RS goats. Figures 4 and 5 also showed that the SA goat and the WAD populations have the greatest diversity, while the RS is genetically midway between these two breeds.

Discussion

Microsatellite markers used in this study are similar to Rout *et al.* (2008) for diversity in Indian goats. All loci studied were polymorphic as indicated by the PIC range between 0.521 and 0.914 with a mean PIC of 0.803. Since Takezaki and Nei (1996) suggested that microsatellite loci for genetic diversity studies should have more than four alleles to reduce the standard error estimates of genetic distances, the total numbers of alleles per locus and high PIC values suggest that these markers are informative for genetic diversity in Nigerian goats and that Nigerian goats possess a wide genetic base that allows for adaptation to a wide variety of ecological environments. Allelic richness in Nigerian goats of 8–26 is higher than Indian goats (8.1–9.7) by Rout *et al.* (2008), average of 7.3 in Iranian goats (Mahmoudi *et al.*, 2010), and average of 5.9 in Canary Island goats (Martínez *et al.*, 2006), but lower than in Spanish Guadarrama goats with 9–36 (Serrano *et al.*, 2009). Gene diversity indicated by H_E had a range of 0.599 for ETH225 to 0.921 for SRCRSP6, which was higher than 0.54 reported by Muema *et al.* (2009), 0.51 reported by Adebambo *et al.* (2011) in Nigerian goats, and essentially overlapped the H_E values of 0.61–0.783 in Indian goats (Rout *et al.*, 2008; Dixit *et al.*, 2010) using the same markers. Literature estimates for mean heterozygosity were 0.70 across all 25 microsatellite loci in six Portuguese goat breeds (Bruno-de-Sousa *et al.*, 2011), 0.72 for Egyptian goats (Agha *et al.*, 2008), 0.63–0.69 in South African goats (Visser *et al.*, 2004), 0.68 in the Brown Short haired goat in the Czech Republic (Jandurova *et al.*, 2004), 0.611–0.84 for Chinese goats (Qi *et al.*, 2009) and 0.61–0.77 in Spanish Guadarrama goats (Serrano *et al.*, 2009). The Nigerian value also significantly departed from the mean of 0.69 in a large group of goat breeds from Europe and the Near East (Cañon *et al.*, 2006). However, some loci had H_O lower than their expected values [SRCRSP5 (0.759), SRCRSP3 (0.098), BM6526 (0.285), SRCRSP9 (0.600) and SRCRSP6 (0.848)] indicating departure from random mating which suggest that they are homozygous in these populations and may indicate on-going selection or may be linked to other loci

Table 3. Measure of gene diversity in studied populations.

Location	No.	Breed	ETH 225	TGLA40	ILSTS5	SRCRSP3	SRCRSP5	BM 6526	SRCRSP10	SRCRSP9	IDVGA 7	SRCRSP6
UNAAB	21	WAD	0.704	0.642	0.561	0.667	0.181	0.570	0.548	0.581	0.773	0.802
UI	30	WAD	0.576	0.564	0.710	0.743	0.528	0.743	0.500	0.500	0.856	0.691
BODIJA	77	WAD	0.549	0.656	0.819	0.891	0.841	0.701	0.836	0.812	0.827	0.910
PH	10	SA	0.628	0.555	0.627	0.853	0.653	0.621	0.733	0.544	0.769	0.744
BODIJA	16	SA	0.620	0.739	0.620	0.805	0.647	0.762	0.724	0.732	0.772	0.860
BODIJA	101	RS	0.538	0.584	0.778	0.831	0.714	0.495	0.818	0.696	0.680	0.896
ASABA	9	RS	0.625	0.688	0.750	0.750	0.000	0.500	0.750	0.625	0.500	0.500
PH	16	RS	0.619	0.729	0.729	0.517	0.458	0.688	0.792	0.721	0.773	0.508
UNAAB	11	RS	0.382	0.777	0.809	0.727	0.556	0.511	0.736	0.500	0.609	0.691

Table 4. Average genetic diversity among breeds by location.

Location	Breed	No.	H_O	H_E
UNAAB	WAD	21	0.814	0.608
	RS	11	0.723	0.716
UI	WAD	30	0.910	0.646
Bodija	WAD	77	0.809	0.784
	RS	103	0.595	0.735
	SA	20	0.619	0.590
Asaba	RS	9	0.629	0.724
PH	SA	14	0.738	0.666
	RS	16	0.633	0.673

No., number of individual goats sampled; H_O, observed heterozygosity; H_E, expected heterozygosity.

Table 5. AMOVA of populations.

Source	df	MS	Est. Var.	%
Among Populations	8	58.961	1.84	29
Within Populations	292	4.473	4.47	71

affecting morphological, productive or adaptive traits undergoing selection (Dixit *et al.*, 2008; Bruno-de-Sousa *et al.*, 2011) or result from mating between relatives and consequent genetic drift, similar to what has been observed in many other goat populations (Agha *et al.*, 2008; Rout *et al.*, 2008; Dixit *et al.*, 2009). Observed F_{IT} values ranged from −0.097 for IDVGA7 to 0.888 for SRCRSP3. Increasing F_{IT} values suggest some measure of homozygosity and heterozygote deficit resulting from relatedness of individuals which may be a consequence of the emergent population structure of Nigerian goats, not previously uncovered by protein polymorphisms based on haemoglobin and transferrin. The presence of negative F_{IS} values at loci ETH225, TGLA40, ILSTS5, SRCRSP10 and IDVGA7 suggests heterozygote deficiencies which have also been reported in other studies on goats (Barker *et al.*, 1997; Luikart *et al.*, 1999; Agha *et al.*, 2008; Rout *et al.*, 2008; Dixit *et al.*, 2009). This heterozygote deficiency may arise due to population sub-structure from pooling together different populations (admixture) in the analysis (Cerda-Flores *et al.*, 2002; Muema *et al.*, 2009). Additional factors include population subdivision owing to genetic drift, null alleles and selection against heterozygotes or inbreeding (Hoarau *et al.*, 2005). Although loci SRCRSP3 and BM6526 showed the highest F_{IS} values indicating fixation of these loci, distinguishing among these factors is generally difficult according to Christiansen *et al.* (1974). The F_{ST} values ranged from 0.048 for ETH225 to 0.191 for SRCRSP3. Low F_{ST} indicates some measure of gene flow between the sampled populations, with ETH225 locus recording the highest gene flow of 18.90. Mujibi (2005) reported a low F_{ST} of 5.8% for WAD goats in Kenya; therefore, gene flow estimates in this study suggest mobility and considerable exchange of genetic material among these goats. These could be attributed to the fact that some of these animals

Table 6. Genetic distance matrix showing genetic identity and diversity by breed and location.

	UNWAD	UNRS	UIWAD	BDWAD	BDRS	BDS	ASRS	PHS	PHRS
UNWAD		1.114	0.686	0.740	0.443	1.286	1.114	0.387	0.967
UNRS	0.328		0.713	0.747	0.740	0.945	0.183	1.019	0.521
UIWAD	0.504	0.490		0.495	0.361	0.578	0.909	0.559	0.595
BDWAD	0.477	0.474	0.610		0.461	0.666	0.755	0.612	0.650
BDRS	0.642	0.477	0.697	0.630		0.762	1.004	0.246	0.465
BDS	0.276	0.389	0.561	0.514	0.467		0.948	1.031	0.722
ASRS	0.328	0.833	0.403	0.470	0.367	0.388		0.943	0.679
PHS	0.679	0.361	0.571	0.542	0.782	0.357	0.390		0.760
PHRS	0.380	0.594	0.552	0.522	0.628	0.486	0.507	0.468	

Nei (1978) genetic distance matrix. Genetic identity is below the diagonal, genetic diversity is above the diagonal.
UNWAD, UNAAB WAD; UNRS, UAAB Red Sokoto goat; UIWAD, UI WAD; BDWAD, Bodija WAD; BDRS, Bodija Red Sokoto goat; BDS, Bodija Sahel; ASRS, Asaba Red Sokoto goat; PHS, PH Sahel; PHRS, PH Red Sokoto goat.

Table 7. Genetic distance matrix showing genetic identity and diversity by breed.

	SA	WAD	RS
SA	****	0.662	0.444
WAD	0.516	****	0.268
RS	0.765	0.641	****

Nei's (1978) genetic distance matrix. Genetic identity is entered below the diagonal, genetic diversity is entered above the diagonal.

originate from northern Nigeria where nomadic pastoralism is the dominant livestock management system and to extensive system of management allowing the animals to roam freely and fend for themselves in most rural households and communities in the South. This enables and reinforces the ability of related animals to meet on pasture to breed or for neighbours to exchange related animals for upkeep or breeding. According to Laval *et al.* (2000), migration may exert a greater effect than mutation or drift on the reduction in genetic differentiation between populations.

Molecular genetic variation was observed to be higher within populations than among populations, which suggest high heterogeneity within populations sampled. The WAD goat stood out clearly as a breed while RS and SA showed a measure of close relationship (Figures 4 and 5). Regardless of location, RS and WAD goats clustered close together, while exhibiting a sharp difference between SA. Toro and Maki-Tanila (2007) suggested that the high genetic diversity observed within population groups could arise from overlapping generations and population mixtures from different geographical locations, with natural selection favouring heterozygosity or subdivision accompanied by genetic drift. The effect of these factors according to Agha *et al.* (2008) is more pronounced when the effective population size is very large, which is supported by the poor infrastructure on ground presently for livestock improvement and lack of proper breeding policy in Nigeria. The genetic distance between SA and RS goats was the closest, while the genetic distance between SA and WAD the farthest. Genetic distance of 0.27 in this study was lower than 0.39 reported earlier between RS and WAD goats by Adebambo (2003) from a smaller sample drawn from several states across Nigeria, which may indicate a higher level of cross-breeding among goats in southern Nigeria concomitant with higher population of humans and by extension higher population density of reared goats.

Figure 4. UPGMA dendrogram showing degree of diversity among goat populations in southern Nigeria.

Figure 5. UPGMA dendrogram showing degree of diversity in Nigerian goats in southern Nigeria.

Conclusion

The use of molecular marker techniques will greatly increase precision of breeding for useful traits and reduce

the amount of time spent in selection (Groeneveld *et al.*, 2010). This knowledge is important to enable the development of appropriate breeding policies and strategies to improve indigenous goat breeds and serve as reference for larger-scale diversity studies. The close clustering of SA and RS is most likely due to the fact that they are both Northern breeds and are transported to the south for sale, while WAD is confined to the southern part of the country. Better understanding of the origins of these breeds will benefit from using additional microsatellite DNA markers, as well as those based on mitochondrial DNA variation.

Statement of Interest: The authors declare that there are no conflicting or competing interests.

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Genetic variability of the Norwegian Fjord horse in North America

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Summary
Pedigrees of a reference population of 1 659 North American Norwegian Fjord horses were traced to founders and analysed for coefficients of inbreeding and genetic variability. Effective population size was 207.8 and there were 641 total founders. Pedigree completeness was close to 100 percent for 6 generations, with 9.8 average complete generation equivalents. The average inbreeding coefficient was 3.2 percent for the entire pedigree and 1.6 percent for pedigrees traced back five generations. Average inbreeding coefficients by year of birth increased until 1983, before decreasing and then stabilizing through 2009. Effective number of founders, ancestors and genomes were 96, 30.0 and 12.7, respectively. Low effective number of founders and ancestors indicate that genetic diversity has been lost in the development of the breed in North America. However, registry-enforced breeding strategies have contributed to lower inbreeding coefficients in the current generation.

Keywords: *founder analysis, genetic diversity, inbreeding, pedigree analysis*

Résumé
Les arbres généalogiques d'une population de référence constituée de 1 659 chevaux Fjord norvégiens de l'Amérique du Nord ont été déterminés et analysés pour ce qui concerne la consanguinité et la variabilité génétique. La taille réelle de la population est de 207,8 animaux et les fondateurs sont au total 641. La généalogie est résultée exhaustive presque à 100 pour cent pour 6 générations, avec une moyenne de 9,8 équivalents de génération complète. Le coefficient moyen de consanguinité est de 3,2 pour cent pour l'arbre généalogique entier et de 1,6 pour cent pour la généalogie remontant à 5 générations. Les coefficients moyens de consanguinité par année de naissance ont augmenté jusqu'en 1983, avant de diminuer et ensuite de se stabiliser jusqu'à fin 2009. Les nombres réels des fondateurs, des ancêtres et des génomes sont respectivement 96, 30 et 12,7. Le faible nombre réel de fondateurs et d'ancêtres indique une perte de diversité génétique lors de la mise en valeur de la race en Amérique du Nord. Toutefois, les stratégies de sélection imposées par le registre ont contribué à faire baisser les coefficients de consanguinité dans la génération courante.

Mots-clés: *analyse des fondateurs, analyse généalogique, consanguinité, diversité génétique*

Resumen
Se han examinado los pedigríes y analizado los coeficientes de consanguinidad y la variabilidad genética de una población de referencia de 1 659 individuos de la raza equina de los Fiordos de Noruega, existentes América del Norte. El tamaño efectivo de la población fue 207,8, con 641 fundadores totales. El pedigrí estaba completo, casi al 100 percent, en las 6 primeras generaciones, con 9,8 equivalentes de la generación media completa. El coeficiente de consanguinidad fue del 3,2 percent para todo el pedigrí y de 1,6 percent teniendo en cuenta sólo las 5 primeras generaciones del pedigrí. Los coeficientes de consanguinidad medios se incrementaron por año de nacimiento hasta 1983, antes de disminuir y luego estabilizarse en 2009. El número efectivo de fundadores, ancestros y genomas fue de 96, 30, y 12,7, respectivamente. El bajo número efectivo de fundadores y ancestros indican que la diversidad genética se ha perdido con el desarrollo de la raza en América del Norte. Sin embargo, los registros obligatorios como parte de las estrategias de mejora han contribuido a reducir los coeficientes de consanguinidad en la generación actual.

Palabras clave: *análisis del pedigrí, análisis fundador, consanguinidad, diversidad genética*

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Introduction

The Norwegian Fjord horse originated in Norway and is noted for its unique and uniform appearance, resulting from selective breeding and an emphasis on genetic purity (Prichard, 2010). Norwegian Fjords were originally used for agricultural purposes and have more recently become popular as sport or leisure mounts. The Norwegian Fjord was introduced in North America in 1900; however, most foundation stock was imported in the 1950s and 1960s. In 1983, the Norwegian Fjord Horse Registry

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(NFHR) was formed to oversee registration, breeding and promotion of Fjords in North America (Prichard, 2010). The formation of this registry has also facilitated increased importation, implementation of reproductive techniques such as artificial insemination, and the advent of formal evaluation processes for breeding animals.

Norwegian Fjords are marked by their consistent coat colour and similar morphological type and conformation as shown in Figure 1 (Bowling and Ruvinsky, 2000). Because the goal of the registry is to maintain this phenotype, strict rules are enforced to ensure genetic purity by prohibiting crossbreeding with animals outside the breed (Norwegian Fjord Horse Registry, 2010). However, because the Norwegian Fjord population in North America is small, continued selection from such a narrow gene pool could result in high inbreeding levels and reduced genetic variability, especially if less related bloodlines are not regularly introduced to the population (Falconer and Mackay, 1996).

An inbreeding coefficient of 3.0 percent for Norwegian Fjord horses was reported using microsatellite data in the Norwegian population (Bjørnstad, Gunby and Røed, 2000). However, the level of inbreeding and genetic variability for the Norwegian Fjord population in North America is unknown. This information would aid the registry's assessment of current breeding practices to sufficiently avoid deleterious effects of inbreeding and reduced genetic variability. Therefore, the objective of this study was to evaluate current levels and historic trends of inbreeding and evaluate the number and contributions of founders and ancestors for the Norwegian Fjord Horse population in North America.

Materials and methods

Data used in this study were provided by the Norwegian Fjord Horse Registry (Webster, NY) and included animal, sire, dam, sex and year of birth. Horses of the current generation (born 2000–2009) were defined as the reference population ($n = 1\,659$), and pedigrees of these animals were traced back to earliest known ancestors. The total pedigree dataset consisted of 6 406 animals, with the earliest recorded ancestor born in 1874. Population summary statistics were calculated using PROC FREQ of SAS 9.2 (SAS Inst., Cary, NC). Pedigree completeness, number of generation intervals, inbreeding coefficients, and effective numbers of founders, ancestors and founder genomes were calculated using PEDIG software (Boichard, 2002).

Figure 1. A stallion from the Fleitner N-97 line exhibiting the desired type and conformation of Norwegian Fjord horses. Photo by Sandy North, used with permission.

Pedigree completeness was evaluated by determining percentage of ancestors known in each generation in both reference and total populations. Number of equivalent complete generations (g_e) was calculated as

$$g_e = \sum \frac{n_i}{2^g}$$

where n_i is the number of known ancestors in generation i and g is the number of known generations for each individual (Boichard, Maignel and Verrier, 1997). Generation intervals were calculated for stallion-daughter, stallion-son, mare-daughter and mare-son pathways, as well as the average generation interval over the four pathways.

Level of inbreeding is measured using an inbreeding coefficient (F), which is the probability that an individual carries two genes identical by descent as a result of matings between related individuals (Falconer and Mackay, 1996). F was calculated using Van Raden's (1992) methods considering five and all available generations in the pedigree. Analysing only five generations of pedigree information emphasizes effects of recent versus historic inbreeding as well as evaluating the pedigree before completeness begins to decline. Effective population size (N_e) was calculated using the change in inbreeding (ΔF) between the reference population and the parents of those individuals ($N_e = [1/2]\Delta F$) (Falconer and Mackay, 1996).

Founder animals were defined as ancestors with two unknown parents. If an animal had one unknown parent, that parent was also considered a founder. Total number of founders may not accurately describe the genetic diversity of a population because it does not account for uneven contributions of particular founders. Therefore, Lacy (1989) introduced the concept of effective number of founders (f_e) to highlight whether certain founders contributed more to the gene pool than others. Effective number of founders is defined as the number of equally contributing founders expected to produce the same genetic diversity as the population under study. Effective number of founders was calculated as

$$f_e = \left[\sum_{i=1}^{N_f} q_i^2\right]^{-1}$$

where N_f is the number of founders and q_i is the genetic contribution of the ith founder.

While f_e accounts for the contribution of the founder population, it ignores loss of genetic diversity that occurs after the foundation of a population and thus may overestimate genetic diversity. Therefore, the calculation of effective number of ancestors (f_a) was proposed by Boichard, Maignel and Verrier (1997) to measure loss in diversity because of the foundation population. Effective number of ancestors is defined as the minimum number of ancestors explaining the complete genetic diversity of the reference population. Based on the 100 most influential ancestors, it is calculated as

$$f_a = \left[\sum_{i=1}^{100} p_i^2\right]^{-1}$$

where p_i is the marginal genetic contribution of the ith ancestor. In an iterative process, the ancestor with the highest contribution is chosen and contributions of all other animals are calculated relative to the contribution of the chosen ancestor. Then the ancestor with the next highest contribution is chosen, and this process continues. Marginal contributions account for the contributions of animals already considered in the recursive process and eliminate redundancies in identification of influential ancestors (Boichard, Maignel and Verrier, 1997). The ratio of f_e/f_a indicates occurrence of bottleneck events in the history of the breed.

Effective number of founders and ancestors still may not entirely demonstrate the effect of random genetic drift in a population. Therefore, Lacy (1989) proposed calculation of effective number of founder genomes (f_g), or the number of founder genomes present in the current population. This parameter accounts for both unequal use of founders and loss of alleles because of bottlenecks and random segregation. The effective number of founder genomes is calculated as

$$f_g = \left[\sum_{i=1}^{N_f} \frac{q_i^2}{r_i}\right]^{-1}$$

where the genetic contribution of the ith founder (q_i) is considered relative to the proportion of the founder's genes that remain in the reference population (r_i). Contributions of founder sire lines were determined by tracing the paternal lineages of all animals born at ten-year intervals from 1939 to 2009.

Results

When analysing the total population, pedigree completeness is approximately 70 percent in the first generation and then steadily decreases (Figure 2). For the reference population, the completeness level is close to 100 percent and does not begin to decline until generation 6. The average complete generation equivalents were 3.9 for the total population and 9.8 for the reference population. Because inbreeding coefficients and other measures of genetic variability are dependent on pedigree depth, only the reference population was used to calculate these parameters. The average generation interval was not significantly different among the four analysed pathways, ranging from 9.0 to 9.3, with a mean of 9.1.

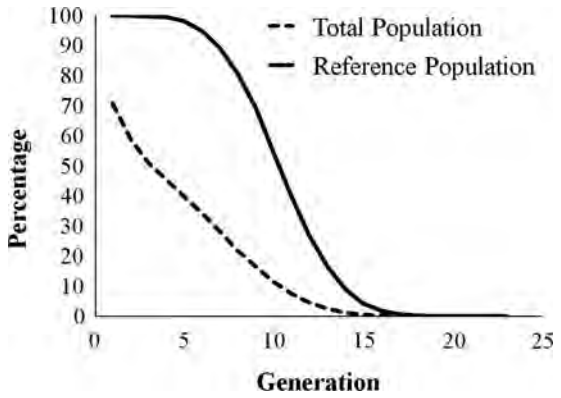

Figure 2. Average percent of pedigree completeness for the total and reference populations.

Population size increased per year of birth in the 1940s and again in the 1980s (Table 1). While there are similar numbers for each sex in the reference population, previous years show a higher number of female animals.

Average inbreeding coefficients were 3.2 and 1.6 percent considering all available and five generations, respectively (Table 2). The average inbreeding coefficient for the reference population was 4.3 percent. Non-zero inbreeding coefficients were found for 78.3 percent of the animals, and average inbreeding coefficient of those individuals was 4.1 percent. The maximum inbreeding coefficient was 38.4 percent, but few individuals demonstrated very high levels of inbreeding. The majority (77.2 percent) of

Table 1. Number of Norwegian Fjord Horses in dataset by year of birth and sex.[1]

Birth year	Male	Female	All horses
<1900	18	13	31
1900–1909	18	22	40
1910–1919	24	37	61
1920–1929	33	87	120
1930–1939	94	165	259
1940–1949	116	272	388
1950–1959	125	295	420
1960–1969	128	326	454
1970–1979	157	431	588
1980–1989	286	630	916
1990–1999	593	877	1 470
2000–2009	787	872	1 659
Total	2 379	4 027	6 406

[1]Reference population.

Table 2. Summary of pedigree analysis of Norwegian Fjord Horse reference population.

Item	
Average inbreeding coefficient, whole pedigree, %	3.2
Average inbreeding coefficient, five-generation pedigree, %	1.6
Effective population size, *n*	207.8
Total founders, *n*	641
Effective founders, *n*	96
Effective ancestors, *n*	30.0
Effective genomes, *n*	12.7
Ancestors explaining 50% of gene pool, *n*	10
Ancestors explaining 75% of gene pool, *n*	29
Ancestors explaining 80% of gene pool, *n*	37
Ancestors explaining 90% of gene pool, *n*	67
Gene pool explained by 100 ancestors, %	94.9

individuals had inbreeding coefficients less than or equal to 15 percent.

Figure 3 illustrates change in inbreeding by birth year for both sexes using either total known pedigree of the reference population or five-generation pedigrees. Inbreeding levels were close to 0 until around 1950, at which point they increased until the early 1980s, with the sharpest increase occurring between 1970 and 1980. After a drop from 1983 to 1997, level of inbreeding remained relatively constant until 2009. From around 1975 onward, inbreeding levels calculated using only a five-generation pedigree were lower than those calculated using the entire pedigree.

The effective population size was 207.8 for the reference population, and the total number of founders was 641 (Table 2). The ratio of effective number of founders to effective number of ancestors, used to detect bottlenecks or other events causing loss of genetic diversity, was 3.2. The 100 most influential ancestors explained 94.9 percent of the gene pool, but only 10 ancestors were required to explain 50 percent of the gene pool. The effective number of founder genomes remaining in the population was small, less than half the effective number of ancestors and only 13 percent of the effective number of founders. Table 3 lists the ten most influential male and female ancestors along with their country of origin and respective marginal and total contributions to the reference population.

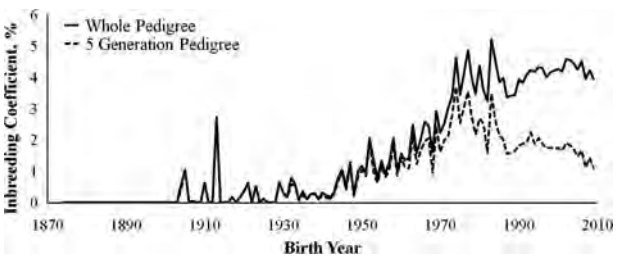

Figure 3. Average inbreeding coefficients by year of birth when tracing five generations or when using the entire available pedigree of the reference population.

Nineteen terminal sires were found by tracing paternal lineages, however only three sires are responsible for about 98 percent of all current paternal lineages (Figure 4). Fleitner N-97 is responsible for 70.9 percent of paternal lineages for horses born in 2009. Across all studied birth years, 69.2 percent of individuals trace to the founder stallion Fleitner N-97, 15.3 percent to Veimar N-475 and 7.0 percent to Baronen N-193. All other terminal sires were responsible for less than 1 percent of paternal lineages.

Discussion

The change in population demographics over time highlights some of the known history of Norwegian Fjord horses in North America. Numbers were low and then increased starting around the 1940s. Most foundation breeding stock were imported in the 1950s and 1960s, and many of these horses were potentially born in the 1940s. Additionally, the increase in the 1980s coincides with importation of 40 young horses from Norway to North America in 1988, referred to as "The Big Lift" (Prichard, 2010). These horses were selected to augment bloodlines in the current gene pool. Further increase in numbers can be attributed to foundation of the Norwegian Fjord Horse Registry and more intensive breed promotion along with a general increase in importation. It is important to note that because the dataset was formed by tracing ancestors of the reference population, only breeding animals are included. Therefore, unequal male-to-female ratios are likely owing to individual stallions covering multiple mares. Also, if non-breeding males were included, ratios should be closer to unity.

These same historical events may also explain changes in inbreeding levels. Mating among related members of foundation stock imported in the 1950s and 1960s resulted in the sharp increase in inbreeding coefficients for horses born between 1970 and 1980. Introgression of breeding stock in the late 1980s allowed inbreeding coefficients to decline. Additionally, the registry's 1986 rule prohibiting matings between parent-offspring, full-sibs and half-sibs could account for the recent drop and stabilization in inbreeding levels (Norwegian Fjord Horse Registry, 2010). Lower inbreeding coefficients based on five-generation also provide support for this hypothesis. Using five-generation pedigrees highlights recent inbreeding levels, and inbreeding coefficients from five-generation pedigrees are much lower, implying historic inbreeding was more substantial.

Heavy use of imported horses in breeding is also evident in the most influential ancestors shown in Table 3. Of the top ten male and female ancestors, only the Purdy Mare has unknown parents and could be considered a founder. However, this mare may not be a single individual but

Table 3. Total and marginal genetic contribution (percent) for the ten male and female ancestors with largest contributions to Norwegian Fjord Horse reference population.

Ancestor	Birth year	Country of origin	Total contribution	Marginal contribution
Stallion				
Oyarblakken N-819	1923	Norway	8.9	8.9
Hakon Jarl N-645	1913	Norway	8.0	8.0
Torbjorn N-1417	1946	Norway	6.3	5.3
Bergfast N-635	1913	Norway	5.0	4.8
Valebu N-1569	1955	Norway	4.9	4.4
King Harald 101-A	1964	United States	5.6	4.3
Orstingen N-1148	1939	Norway	3.9	3.9
Molnesblakken N-792	1920	Norway	5.9	2.2
Lidaren N-1653	1961	Norway	4.0	2.0
Rudaren N-1853 C-74 211-A	1978	Norway	4.4	2.0
Total				45.9
Mare				
Selma N-2423	1926	Norway	4.9	4.9
Purdy Mare[1]	1961[1]	Unknown	4.0	4.0
Dokka N-3580	1935	Norway	2.6	2.6
Rita D-4750 C-3	1965	Denmark	1.2	1.1
Tosen D-4553 C-2	1961	Denmark	1.2	1.1
Runa N-12516	1958	Norway	2.5	1.1
Molly N-11714	1951	Norway	1.4	1.0
Sunngard H-S04	1973	Netherlands	1.1	1.0
Monlaug N-12834	1955	Norway	1.4	0.9
Tordis N-3021	1925	Norway	1.2	0.8
Total				18.4

[1]Accuracy of progeny reporting and year of birth for this individual is uncertain, see discussion for more detail.

instead originates from a group of mares belonging to a single owner, and many of his breeding records were lost. Therefore her pedigree is unclear. Most major ancestors were born after 1940 and were likely part of the stock imported in the 1950s and 1960s. All but one sire originated in Norway, while there were two Danish and one Dutch mare. Currently, no North American born horse has provided considerable influence to the gene pool. Only 1 North American born horse ranks in the top 10 ancestors (King Harald) and 4 others are present in the top 100, each with less than 1 percent marginal contribution. This is not particularly surprising because the breed is relatively young in North America and importation remains fairly common.

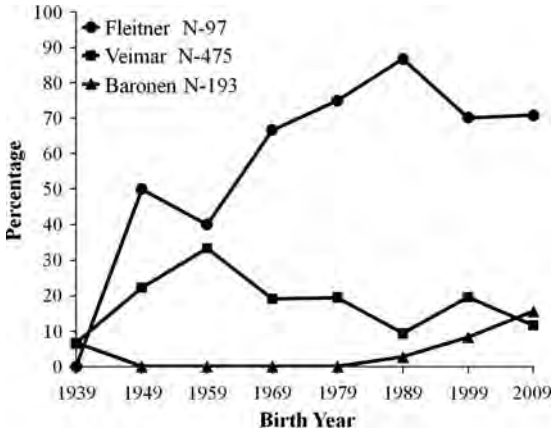

Figure 4. Contributions of male founders to sire lines found by tracing paternal lineages of the entire population at ten-year intervals.

Pedigree depth and completeness can affect inbreeding coefficients as increased depth will most likely increase inbreeding coefficients by identifying common ancestors further back in the pedigree (MacCluer *et al.*, 1983). In this study, pedigree depth and completeness was similar to that found in other populations (Valera *et al.*, 2005; Hamann and Distl, 2008). Although pedigree depth (measured by g_e) was less than that of Lipizzan horses (15.2; Zechner *et al.*, 2002), it was higher than several other studies, including Spanish Arabs (2.97; Cervantes *et al.*, 2008) and Asturcón ponies (5.7; Royo *et al.*, 2007). Therefore, pedigree depth should be sufficient to accurately calculate inbreeding in this population. Generation interval calculated here was also similar, although slightly shorter, than that reported in other breeds (Moreaux *et al.*, 1996; Sevinga *et al.*, 2004; Hamann and Distl, 2008). Populations with longer generation intervals generally have extensive evaluation procedures that have only recently been introduced in North America for the Norwegian Fjord.

Bjørnstad, Gunby and Røed (2000) found an inbreeding coefficient of 3.0 percent in Norwegian Fjords born in Norway using microsatellite data. The inbreeding coefficient found here indicates that the population in North America has not become substantially more inbred than the native population. Overall, the inbreeding coefficient is lower than what is reported in other horse populations.

Inbreeding coefficients closest to those reported here are 3.08 percent for Arabians raised in France (Moreaux *et al.*, 1996), 4.7 percent for the Asturcón pony of Spain (Royo *et al.*, 2007), 3.06–5.31 percent for Polish Arabians (Głażewska and Jezierski, 2004) and 5.01 percent for Noriker draught horses (Druml, Baumung and Sölkner, 2009). All of these populations are relatively small and effectively closed to crossbreeding. However, many other populations prohibiting crossbreeding reported higher inbreeding coefficients ranging from 6.0 to 15.6 percent (Mahon and Cunningham, 1982; MacCluer *et al.*, 1983; Cunningham *et al.*, 2001; Zechner *et al.*, 2002; Sevinga *et al.*, 2004; Valera *et al.*, 2005; Poncet *et al.*, 2006; Cervantes *et al.*, 2008). Many of these populations also had smaller effective population sizes and increased pedigree depth. Populations with lower inbreeding coefficients (0.7–1.86 percent) represent larger populations and many have a more open policy concerning crossbreeding (Moreaux *et al.*, 1996; Hamann and Distl, 2008). Many also had slightly longer generation intervals.

The discrepancy between total and effective number of founders indicates that there was an uneven representation of breeding animals in the formation of this breed. However, effective number of founders is moderate compared with other populations reported in the literature, which range from 18.1 to 333 (Moreaux *et al.*, 1996; Cunningham *et al.*, 2001; Zechner *et al.*, 2002; Valera *et al.*, 2005; Ducro *et al.*, 2006; Royo *et al.*, 2007; Cervantes *et al.*, 2008; Hamann and Distl, 2008). Norwegian Fjord horses were most similar to small populations closed to crossbreeding such as Trotteur Français (70; Moreaux *et al.*, 1996), Franches-Montagnes (68.7–75.7; Poncet *et al.*, 2006), and Noriker draught horses (117.2; Druml, Baumung and Sölkner, 2009).

Effective number of ancestors was fairly high and similar to Noriker draught horses (29.3; Druml, Baumung and Sölkner, 2009). Only Spanish Arabs and Hanoverians reported higher effective number of ancestors at 39.5 and 77.73, respectively (Cervantes *et al.*, 2008; Hamann and Distl, 2008). However, the ratio of f_e/f_a was quite high at 3.21, indicating disproportionate use of some individuals resulting in random loss of genetic diversity. Additionally, a majority of influential ancestors seem to have been part of initial importations in the 1950s and 1960s. This importation could have created a bottleneck event and explains some of the reduction in genetic diversity. This ratio was similar or slightly smaller than that found in Hanoverians (3.15; Hamann and Distl, 2008), Franches-Montagnes (3.61–3.98; Poncet *et al.*, 2006) and Noriker draught horses (4.0; Druml, Baumung and Sölkner, 2009). Other breed populations reported lower ratios, implying that loss of diversity because of uneven use of sires is more extreme in North American Norwegian Fjords. The difference between effective number of founder genomes and effective number of ancestors was also quite large, further indicating random loss of genetic diversity.

The small number of sire lines also shows uneven contributions of founder sires and potential for loss of genetic diversity. Fleitner N-97's sire line currently provides the highest contribution and is also the terminal sire for nine of the ten most influential male ancestors through his son Njal N-166. However, although Veimar N-475's sire line is declining, he is the terminal sire for the top male ancestor. Baronen N-193's sire line was non-existent prior to 1989 but has been increasing in recent generations. Typically a small number sire lines are responsible for a majority of paternal lineages in horse populations, and in many populations a single sire line becomes dominant. Populations with fewer sire lines tended to have higher levels of inbreeding and lower effective numbers of founders and ancestors (Cunningham *et al.*, 2001; Royo *et al.*, 2007; Cervantes *et al.*, 2008). In the case of Thoroughbreds, which have one sire line responsible for 95 percent of modern horses, the average inbreeding coefficient was one of the highest reported in the literature for horse breeds (Cunningham *et al.*, 2001).

Conclusion

This study indicates that recent breeding strategies employed by the NFHR for the North American population of Norwegian Fjord horses have prevented further increase in inbreeding levels. If these policies continue to be enforced, inbreeding should remain constant or could decrease. However, low effective number of founders and ancestors and the high ratio of these two parameters show that this breed has undergone random loss of genetic diversity, most likely owing to uneven use of particular breeding individuals and overall small population size. Because of this loss, the gene pool for this breed is relatively small and attempting to select unrelated individuals will become increasingly difficult. Also, many alleles present in the founders of the breed may already permanently lost. Therefore, even though inbreeding is not extreme and no deleterious effects have been reported, further reduction of genetic variability is still a concern. The registry may consider utilizing support provided by organizations such as the American Livestock Breeds Conservancy to educate breeders in methods to minimize inbreeding and increase genetic diversity in relatively rare breeds (American Livestock Breeds Conservancy, 2010). Although Norwegian Fjord horses in North America show less loss than other breeds of small population size and closed studbooks, further loss of genetic diversity should be prevented. Breeders should be encouraged to utilize more diverse bloodlines to broaden the genetic base of this population.

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Estimating farmers' preferences in selection of indigenous chicken genetic resources using non-market attributes

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Summary
The objective of this paper was to estimate the farmers' preferences based on the non-market traits in selection, breeding and conservation of indigenous chicken. The study was carried out in four selected counties of Kenya. Data were collected using structured questionnaires with the use of multi-attribute elicitation techniques applied to 450 rural households. Conjoint analysis through an ordered probit model was used to analyse the data. The study identified traits preferred by the farmers based on their current low-input production circumstances. Using these traits, indigenous chicken can be selected for higher productivity and performance while retaining their diversity and adaptability. In general, the determination of the importance of various attributes elucidates to the stakeholders some valuable aspects that would assist them in overcoming some of the major constraints of indigenous chicken production in rural areas and at the same time provides vital information for selection, conservation and development of breeding programmes.

Keywords: *genetic resource, indigenous chicken, non-market attribute, preference, selection and conservation*

Résumé
Ce document avait pour objectif l'estimation des préférences des agriculteurs sur la base de caractères non marchands dans le choix, la sélection et la conservation des poules indigènes. L'étude a été réalisée dans quatre comptés choisis du Kenya. Les données ont été collectées en utilisant des questionnaires structurés, préparés par des techniques d'élicitation multi-attributs, soumis à 450 ménages ruraux. L'analyse conjointe par un modèle probit ordonné a été utilisée pour examiner ces données. L'étude a identifié les caractères préférés par les agriculteurs sur la base de la situation courante de production à faible apport d'intrants. En utilisant ces caractères, on peut sélectionner les poules indigènes pour une productivité et une performance plus élevées tout en gardant leur diversité et leur adaptabilité. En général, la détermination de l'importance d'attributs différents explique aux parties prenantes certains aspects précieux qui pourraient les aider à surmonter quelques-unes des principales contraintes de la production des poules indigènes dans les zones rurales et fournit, en même temps, des informations essentielles pour la sélection, pour la conservation et pour le développement des programmes de sélection.

Mots-clés: *poules indigènes, ressources génétiques, attribut non marchand, préférence, sélection et conservation*

Resumen
El objetivo de este trabajo fue estimar las preferencias de los ganaderos basadas en rasgos que no son importantes desde el punto comercial en la selección, la mejora genética y la conservación de razas indígenas de gallinas. El estudio se llevó a cabo en cuatro condados seleccionados de Kenia. Los datos se recopilaron por medio de cuestionarios con el uso de técnicas de obtención de múltiples atributos aplicados a 450 familias rurales. Se utilizó el análisis conjunto a través de un modelo Probit ordenado para analizar datos. El estudio identificó los rasgos preferidos por los ganaderos en base a sus circunstancias actuales de producción de bajos insumos. Por medio del uso de estos rasgos, los pollos indígenas pueden ser seleccionados para una mayor productividad y rendimiento, manteniendo su diversidad y adaptabilidad. En general, el hecho de determinar la importancia de varios atributos aclara a los interesados algunos importantes aspectos que les ayuden a superar algunas de las principales limitaciones de la producción aviar basada en razas indígenas en las zonas rurales, y, al mismo tiempo, proporciona información esencial para la selección, la conservación y el desarrollo de programas de mejora.

Palabras clave: *gallina indígena, recurso genético, atributos no importantes desde el punto de vista comercial, preferencia, selección y conservación*

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Introduction

Indigenous chicken (IC) production is an important activity in most parts of Africa (Kitalyi, 1998; Birol and Asare-Marfo, 2008). Despite several challenges, IC rearing fulfils a number of monetary and non-monetary functions. These are consumption, income generation, cultural ceremonies, pest control and manure among others (Muchadeyi *et al.*, 2004; Mtileni *et al.*, 2009). ICs require minimal investment from the keepers, their productivity proves easy to improve in a rural setting (von Dach, Sommer and Wenger, 2007). They also provide pathways out of poverty to the disadvantaged groups (Randolph *et al.*, 2007; Gueye, 2009; Pica-Ciamarra, 2009). IC farming as a source of income in this respect is promising. Despite the introduction of exotic breeds and lines, ICs are still the most abundant in developing countries (Gueye, 2002). In Kenya, they account for over 70 percent of the total poultry population (Kaudia and Kitalyi, 2002; Olwande *et al.*, 2010).

The dominant production systems in many parts of developing countries, especially in the rural areas of Africa, are mainly subsistence based, where some of the world's surviving farm animal genetic resources are found (CBD, 1992; Drucker and Anderson, 2004). The IC production systems are normally characterized by the levels of inputs and various outputs. These include the free range (FR) or scavenging system, the semi-scavenging or semi-intensive system and the confined system (CS) or full ration system (Kitalyi, 1998; Tadelle, Kijora and Peters, 2003a; Maphosa *et al.*, 2004). The ICs possess unique adaptive traits such as disease and stress tolerance, ability to scavenge for food and escape predators that permit them to survive and reproduce under harsh climatic, nutritional and management conditions typically associated with low-input–output production systems (Mwacharo, Jianlin and Amano, 2006; Dana *et al.*, 2010). The low productivity of IC has therefore resulted in attempts to improve them in the past. Attempts to upgrade IC with exotic breeds contribute to the loss of genetic diversity and present IC with extinction risks despite their number.

Kenya, in particular, has had many poultry improvement programmes such as the cockerel and pullet exchange, which targeted the upgrading of IC (Kamau, 2000). Even though many positive aspects were highlighted by the proponents of these programmes, they failed to take into account several major concerns. These include consideration of the farmers' preferences, conservation of the existing genetic resources, adaptability of the introduced breeds and survival of subsequent upgraded generations in the low-input systems. Selection and breeding errors may take many years to be identified and even then corrections are difficult (Pease, 1990). Therefore, the aforementioned factors need to be considered before any improvement programme is put in place in the future.

This paper is motivated by the fact that farmers want an IC genetic resource that is well adapted to their local conditions while meeting their economic and social requirements. The starting point is then to look at the farmers' preferences based on the non-market traits and using them for selection and breeding to combine all the specified characteristics suggested by the farmers. Breeding is the most important component of the management, utilization and development of animal genetic resources. Breeding and better management practices may lead to profitability of improved genetics at farm level. Such economic improvement especially on smallholder IC farms may add up to welfare gains and improved food security at the national level. Breeding *per se* has always been influenced by the current biological, genetic, technological and statistical knowledge (Hoffman and Scherf, 2006). It also plays an important role in genetic resource conservation. Hence, it is important to understand livestock keepers' perceptions and attitudes (Zander, Drucker and Holm-Müller, 2009). However, since we do not know what will be valuable in future, conservation of maximum diversity is necessary since it maximizes the probability that the conserved genetic resources contain a desirable extreme for the unknown quality (Woolliams and Toro, 2007). Therefore, breeders are constantly faced with the continuous challenges of improving IC.

To estimate farmers' preferences, several approaches have been used to attain an approximate value of animal genetic resources. Stated preference methods have been applied to evaluate, measure or estimate non-market attributes such as conjoint analysis (Sy *et al.*, 1997; Tano *et al.*, 2003; Makokha *et al.*, 2007), choice experiments (Scarpa *et al.*, 2003; Nielsen and Amer, 2007; Ouma, Abdulai and Drucker, 2007; Omondi *et al.*, 2008; Roessler *et al.*, 2008; Ruto *et al.*, 2008; Zander and Drucker, 2008; Girma, Awudu and Clemens, 2009; Zander, Drucker and Holm-Müller, 2009) and the contingent valuation method (Kamuanga *et al.*, 2001) among others. Moreover, Nielsen and Amer (2007) identified that the application of choice experiment methods may increase farmer acceptance of breeding objectives. The objective of our study was to estimate the farmers' preferences based on the non-market traits in selection, breeding and conservation of ICs. To achieve this, we utilized the conjoint analysis. Conjoint analysis enables the measurement of farmer preferences or ratings of existing or possible profile attributes in terms of the attribute or trait itself and its level. The purpose of conducting a conjoint experiment is to ascertain the relative importance of IC traits, as well as their most preferred levels. This method is also used to determine the most preferred combination of attributes for each production system and is based on the farmers' reasons for keeping IC.

Materials and Methods

The study area and sampling design

The study was conducted in the four selected counties of Kenya. These included Kakamega, Siaya, Bomet and

Narok. The sampling frame for this study included all the households in the selected regions. A total of 450 respondents were interviewed during the survey that started in October 2009 and ended in February 2010. The survey also collected information from the markets and consumers in the areas visited.

Selection of attributes and levels of IC

A list of attributes of the IC and their levels were developed based on the discussions with key informants and groups of researchers in the field of animal breeding and economics. The field questionnaires were then developed with the list of attributes and levels, including socio-economic information required from the farmers. It was then applied in a pilot study in Nakuru County as interviews with individuals and groups of farmers. This was followed by a survey in 2007. At this stage, some of the attributes not considered by farmers as useful were identified and subsequently removed. This significantly reduced the number of attributes to be evaluated by the respondents in the main survey. The IC types that were common in most parts of the study areas were the normal feathered, naked neck, feathered shanks, giant, crested head, dwarf sized and frizzle-feathered. Selection of the traits for profile rating choice experiment was achieved through pair-wise ranking from a total of 14 traits given the variation of the ICs. This was done at two levels: (i) traits perceived as most important by farmers and (ii) traits considered important for selection and breeding for both cocks and hens (details are given in the Experimental design section). The attribute and their levels were made as simple as possible and realistic for the final choice experiment survey. Following Louviere, Hensher and Swait (2000), the attribute's levels for this study were effect-coded. Table 1 shows the attributes and levels of IC traits perceived as most important and those considered by farmers for breeding and selection purposes.

Table 1. Attributes and levels of IC traits perceived as most important and considered for breeding and selection purposes.

Traits/attributes	Attribute levels/ alternatives	Cocks/hens
Growth rate	Rapid = 1, slow = −1	
Body size	Large = 1, small = −1	
Egg yield	High = 1, low = −1	
Fertility	High = 1, low = −1	
Disease resistance	Resistant = 1, susceptible = −1	
Heat tolerance	Good = 1, poor = −1	
Temperament	Easy to handle = 1, difficult to handle = −1	
Breeding and selection purposes		
Growth rate	Rapid = 1, slow = −1	Cocks and hens
Body weight at sexual maturity	Good = 1, poor = −1	Cocks and hens
Egg production/bird/year	High = 1, low = −1	Hens
Broodiness	Good = 1, poor = −1	Hens
Mothering ability	Good = 1, poor = −1	Hens
Disease resistance	Resistant = 1, susceptible = −1	Cocks and hens
Hatchability	Good = 1, poor = −1	Hens
Plumage colour	Good = 1, bad = −1	Cocks
Fighting ability	Good = 1, poor = −1	Cocks

Experimental design

In Table 1, seven traits perceived by farmers as important were selected: five traits for cocks and seven for hens. Using the selected traits in the experiment, a full factorial design resulted in 128 ($2^7 = 128$) scenarios or combinations. Since farmers would have difficulty in providing the ratings for all 128 profiles, an orthogonal fractional factorial design was used to reduce the number of scenarios to be rated to 8. A fractional factorial design is a sample of attribute levels selected from a full factorial design without losing information to effectively test the effects of the attributes on producer's preferences (Fields and Gillespie, 2008). A total of 450 individual interviews or choice experiments were therefore conducted.

In order to ease the process of data collection and improve communication between enumerators and respondents, well-educated survey enumerators and those who understood the local language and actually came from these specific regions of study were selected and trained on the questionnaire. Based on the pilot and the previous survey experience, in the first section of the main questionnaire's preference ranking or rating, the traits or attributes were divided into four major categories: performance (growth rate, size and yield-egg numbers), reproductive (fertility and prolificacy), functional (disease tolerance, heat tolerance, drought tolerance and temperament) and aesthetic (plumage colours, egg sizes, fighting ability, meat quality and shape). An introduction of about 5–10 minutes was given by the enumerator to each respondent before they were asked to provide preference ratings for the profiles of the IC attributes. The attributes and levels were summarized in the questionnaire in a simple table that could be easily understood and backed up by some illustrations describing the traits. Each enumerator carried a table separately. The farmers were first asked to rank the traits in each of the four categories in ascending order by giving the value 1 to the most preferred trait. Similarly, in the second stage they were asked to rate on the scale 0–10, the profiles they considered containing the traits of primary importance, giving the most highly preferred trait the value of 10.

In the third stage, farmers were asked to rate the profiles for selection and breeding purposes for cocks and hens separately. Overall, the rankings and ratings of the traits by the farmers doing the assessment were based on their perceptions, indigenous knowledge and experiences with the IC. Comparatively the farmers were asked to rank

generally the traits that they considered important without taking into consideration the profiles, the categories and the sex of the IC, unlike in the previous stages. This was repeated for the traits intended for selection and breeding. The measure of the agreement for these rankings among the farmers was done using the Kendall's coefficient of concordance (W) and alternatively the weighted indices (in equation 1).

The high and significant correlation values for W would indicate close agreement on the rankings of the traits being chosen by the farmers and vice versa. This was important in comparing the results from the conjoint relative scores and simple ranking or indexing. Only the conjoint relative importance results are presented in this paper. The indices were calculated using the following formula (Bett *et al.*, 2009):

$$I_i = \begin{pmatrix} m \\ \vdots \\ 2 \\ 1 \end{pmatrix} \left[\sum_{j=1}^{m} X_j \right]_i \Bigg/ \sum_{k=1}^{n} \left[\begin{pmatrix} m \\ \vdots \\ 2 \\ 1 \end{pmatrix} \sum_{j=1}^{m} X_j \right]_k, \qquad (1)$$

where I_i is the index value, X_j is the percentage of respondent ranking the attribute or trait i in the jth rank, m is the last rank of the trait or attribute and k is the sum of ranks for n number attributes or purposes. The indices represent weighted averages of all rankings for a particular IC attribute.

Other information hypothesized to influence the farmers' preferences was collected including the major reasons for rearing IC. Under this, six major reasons for keeping IC were identified or suggested, including home consumption, cash income derived from the sale of eggs and live birds, asset building, emergency cases, manure, culture, ceremonies/rituals and lastly for commercial cock fighting. The three existing production systems identified by the farmers were: FR, semi-confined (SC) and confined full-ration systems. The systems of production and the reasons for rearing IC were useful in segmenting the farmers according to their preferences. To solicit more information, farmers were asked to give the reasons for culling and selection of their stock.

Stated preference choice modelling

The Lancastarian conceptual framework was used as a basis of modelling producer preferences in this study. This framework approach suggests that goods are not the direct object of utility; rather, it is the characteristics of the goods from which utility is derived (Lancaster, 1966) and utility from a good can be decomposed into separate utilities (Louviere, 1994).

The probit model specifies utility with an observed and an unobserved component. It is also linearly related to the attributes (Louviere, 1994). When presented with a set of alternatives, individuals will choose an alternative that maximizes their utility. Since the stated preference choice responses are ordered in nature, this study employed the use of an ordered probit. In this case, the observed response can be modelled by considering a latent (not observable) variable y_i^*, which depends linearly on the explanatory variables X.

$$y_i^* = X_i\beta + \varepsilon_i \quad \text{with} \quad \varepsilon_i \sim N(0, 1), \qquad (2)$$

where y_i^* is the dependent variable taking on values 0, 1, 2, 3, ..., J, and is viewed as outcomes of continuous process. The dependent variable is observed as the likelihood to prefer or choose certain alternative. β is the vector coefficients, X_i is the vector of independent variables and ε is the error term. Equation (2) can be estimated through multinomial logit. However, the multinational logit or probit model, which allows for more than two categories, suffers from the well-known "independence of irrelevant alternatives" assumption (Greene, 2003), as errors are assumed to be independent from each category. To avoid this problem, the ordered probit model that allows the dependent variable to assume values which are ordinal in nature are used in this study. Therefore, the decision-making process or the preference for a particular alternative for farmer i is as follows:

$$y_i = \begin{cases} 0 & \text{if} \quad y* \le \gamma_0 \\ 1 & \text{if} \quad \gamma_0 \le y* \prec \gamma_1 \\ 2 & \text{if} \quad \gamma_1 \le y* \prec \gamma_2 \\ \vdots & \vdots \\ \vdots & \vdots \\ J & \text{if} \quad \gamma_{J-2} \le y* \end{cases}. \qquad (3)$$

The threshold values γ_j's are parameters to be estimated, as are the unknown coefficients vector β. The ordered probit model provides the thresholds that would indicate the levels of inclination towards preference of an IC alternative, and so there is no arbitrary assumption about the magnitudes of differences between categories of the dependent variables. Calculating the probabilities of y_i being in a particular rank or rating entails the use of the estimated threshold values and can be estimated as

$$\begin{aligned} &\text{Prob}(y = 0) = \Phi(-X_i\beta), \\ &\text{Prob}(y = 1) = \Phi(\gamma_1 - X_i\beta) - \Phi(-X_i\beta), \\ &\text{Prob}(y = 2) = \Phi(\gamma_2 - X_i\beta) - \Phi(\gamma_1 - X_i\beta), \\ &\qquad\qquad \vdots \\ &\text{Prob}(y = J) = 1 - \Phi(\gamma_{J-2} - X_i\beta). \end{aligned} \qquad (4)$$

where $\Phi(-X_i\beta)$ denotes the cumulative standard normal distribution function, $X_i\beta$ is a set of specific values of X for the estimated coefficients (β) and the threshold values

(γ's). The coefficients β are estimated through the maximization of the log-likelihood function.

Empirical procedure

The selection of important non-market economic attributes is estimated using preference ratings by farmers. The choice variable is related to utility as follows:

$$y = 1 \text{ if } 0 < U < \gamma_1, \quad y = 2 \text{ if } \gamma_1 < U < \gamma_2, \ldots, y = J \text{ if } U > \gamma_{J-2} U = u(X, \gamma), \tag{5}$$

where U is the unobserved utility level, Y's are the preference rankings and γ's are the threshold variables linking the respondent's actual preferences with the ratings. The stated preference choice ranking or rating model can be generally presented as

$$y = \alpha + \beta^1 X + \mu W + \varepsilon_i, \tag{6}$$

where y is a vector of preference ratings $(0, 1, 2, \ldots, J)$ of the attributes, X is a vector of variables representing the IC's attributes (growth rate, body size, disease resistance, fertility, plumage colours, etc.). W captures the interaction of trait levels and characteristics of the household, β^1 is a vector of marginal utilities for the level of traits, μ is a vector of marginal impacts of the interaction between the levels of traits and individuals background and ε_i is the disturbance term.

The relative importance procedure

The conjoint analysis gives some trade-offs between the traits. Its power and success as a multi-attribute decomposition method rely on its ability to give the relative importance of the individual traits. The relative importance in this study was described as the average values that were ascribed by producers to the traits. The relative importance scores of the attributes were estimated, therefore, as

$$\text{RI} = \frac{\text{Range}_i \times 100}{\sum \text{Ranges}}, \tag{7}$$

where RI is the relative importance of the attributes. The range is described as the difference between the highest and the lowest attribute utility levels, which is divided by the sum over all utility ranges.

Three models were analysed for main effects and seven interactions were carried out. The three models analysed were for traits generally preferred by farmers and the traits of cocks and hens important for breeding purposes. The seven interactions with the preference ratings done were based on the reasons for keeping and the IC production or rearing systems. To achieve the results, an ordered probit model was used and subsequently analysed using Limdep version 8.0 statistical software (Greene, 2002).

Results

Preference profile rating results of IC traits

Table 2 shows the main effects of the levels of IC traits on ratings by farmers for traits perceived as most important, whereas Table 3 presents the main effects for the levels of the preferred IC cock and hen performance traits on ratings by farmers for selection and breeding purposes. The independent variable coefficients indicate the part-worths (marginal utilities). Part-worth can be defined as a number that represents the value that an average producer or farmer places on one of the levels of an attribute. More value is indicated by high part-worth, while a low part-worth indicates less value. The threshold values on the other hand represent the link between the ratings and utilities. In all the three models, the values are increasing and positively significant at $P < 0.01$. This indicates that there is no misspecification error.

In Table 2, the χ^2 is significant with a value of 2334.47 and a log likelihood of −6925.11. All the variables have the expected signs and therefore indicate that they are relevant in explaining the respondent's preference ratings. In model I, all the variables were significant except the trait level if "easy to handle", implying farmers' indifference with the trait. The rapid growth rate, high fertility level and high disease resistance level were all positive and highly significant at $P < 0.01$. Heat tolerance was significant at $P < 0.05$, whereas small body size and low egg yield are negatively

Table 2. Main effects for levels of IC traits on ratings by farmers for traits perceived as most important.

Variable	Model I Coefficient	Standard error	*P*-value
Constant	1.359***	0.026	0.000
Rapid growth rate	0.108***	0.039	0.006
Small body size	−0.226***	0.037	0.000
Low egg yields	−0.795***	0.048	0.000
High fertility rate	0.345***	0.038	0.000
Disease resistance (resistant)	0.123***	0.039	0.002
Good heat tolerance	0.084**	0.038	0.029
Temperament (easy to handle)	0.001	0.038	0.978
Threshold variables			
Mu (1)	0.339***	0.096	0.000
Mu (2)	0.376***	0.020	0.000
Mu (3)	0.673***	0.025	0.000
Mu (4)	1.026***	0.028	0.000
Mu (5)	1.350***	0.032	0.000
Mu (6)	1.719***	0.034	0.000
Mu (7)	1.746***	0.034	0.000
Mu (8)	2.244***	0.041	0.000
Mu (9)	3.317***	0.093	0.000
Log likelihood function	−6925.11		
Restricted log likelihood	−8092.34		
Chi-squared	2334.47		
Degrees of freedom	56		
Significance level	0.0000		

*Significant at 10%; **significant at 5%; ***significant at 1%.

Table 3. Main effects for the levels of preferred IC cocks and hen performance traits on ratings by farmers for selection and breeding purposes.

Variable	Model II (Cocks) Coefficient	Standard error	Model III (Hens) Coefficient	Standard error
Constant	1.399***	0.028	1.202***	0.025
Rapid growth rate	0.168***	0.041	0.081*	0.046
Heavy body weight at sexual maturity	0.350***	0.042	0.043	0.046
Disease resistance (resistant)	0.229***	0.043	0.214***	0.046
Good plumage colour	0.094**	0.042	–	–
Good fighting ability	0.136***	0.042	–	–
High egg yield	–	–	0.293***	0.044
Poor hatchability	–	–	−0.080*	0.045
Good broodiness	–	–	0.103**	0.046
Good mothering ability	–	–	0.474***	0.047
Threshold variables				
Mu (1)	0.409***	0.022	0.316***	0.017
Mu (2)	0.430***	0.023	0.331***	0.018
Mu (3)	0.742***	0.026	0.627***	0.022
Mu (4)	1.136***	0.029	0.991***	0.025
Mu (5)	1.423***	0.030	1.286***	0.027
Mu (6)	1.741***	0.032	1.630***	0.030
Mu (7)	1.755***	0.032	1.660***	0.031
Mu (8)	2.194***	0.036	2.053***	0.037
Mu (9)	2.674***	0.046	2.488***	0.054
Log likelihood function	−7559.26		−7431.21	
Restricted log likelihood	−8036.90		−8036.09	
Chi-squared	955.28		1209.76	
Degrees of freedom	40		56	
Significance level	0.0000		0.0000	

*Significant at 10%; **significant at 5%; ***significant at 1%.

significant at $P < 0.01$. The negative part-worth values implied that the preferences of the farmer would be lower if there were changes in the attribute levels.

Similarly, Table 3 shows the main effects of performance traits preferred by the farmers on selection and breeding purposes for models II (cocks) and III (hens). The two models were significant with χ^2 values 955.28 and 1209.76, with log likelihoods of −7559.26 and −7431.21, respectively. All variables in model II and most in model III were significant with expected signs.

In model II, all the five trait utility levels are positive and significant. Rapid growth rate, heavy body weight at sexual maturity, resistance to diseases and good fighting ability were significant at $P < 0.01$ although good plumage colour was significant at $P < 0.05$.

In model III, most of the traits were significant except for heavy body weight at sexual maturity. Rapid growth rate was significant at $P < 0.10$. Good broodiness was significant at $P < 0.05$ while disease resistance, high egg yield and good mothering ability were highly significant at $P < 0.01$. However, poor hatchability was negatively significant at $P < 0.10$.

Interaction effects

The interactions were carried out to determine if the farmers were heterogeneous in their preferences. This was based on the IC traits perceived as of primary importance and those for selection and breeding within the different kinds of production systems and reasons for keeping IC. The three existing production systems identified by the farmers were used as the first way of segmenting the farmers. These were: the FR, SC and the confined system (CS). The second approach of grouping the farmers was to use the reasons for keeping IC. This was based on the assumption that farmers had varying reasons to keep IC; therefore, the traits they preferred differed significantly. From the seven identified reasons to keep IC, four highly ranked reasons were picked. These were home consumption (R1), cash income (R2), emergency (R3) and asset building (R4). Other reasons from this ranking were cultural, manure and cock fighting. The ranking criterion was based on the index method (equation 1). The marginal values were then calculated for all the interactions. Table 4 shows the different trait levels of primary importance interactions with the production systems and reasons to keep IC on ratings.

Most of the incremental part-worth values for FR were significant while only growth rate was significant for SC. In CS, egg yield, fertility, disease resistance and heat tolerance were significant. To understand the meaning of these coefficients for instance, a value that an average farmer in that scenario would ascribe to rapid growth rate was 0.108 (given in Table 2). There was an incremental value of 0.371 and 0.120 under FR and SC, respectively. Adding up the incremental part-worth with 0.108 ascribed by an average farmer gives 0.479 for FR and 0.228 for SC, which basically implies that the farmers placed a higher value on rapid growth rate under FR than in the other systems. The non-significant coefficient value for rapid growth rate under CS means that the preference was not different from 0.108 ascribed by an average farmer, therefore not considered. The same criterion applied to all non-significant coefficients.

Across the production systems, the trait level "easy to handle" was not significant, which implied that segmentation based on this trait was also not possible. However, it was possible to segment using high-fertility trait since farmers preferred this trait for reasons of building the

Table 4. Interactions of the levels of traits considered to be of primary importance and the farm and farmer characteristics' influences on the producer preference ratings.

	Production systems			Reasons for keeping IC				Average farmer
	FR	SC	CS	R1	R2	R3	R4	
Rapid growth rate	0.371***	0.120**	−0.051	−0.361	0.387*	−0.083	0.038	0.108
Small body size	0.454***	0.110	0.178	−0.347	0.558**	−0.043	−0.045	−0.226
Low egg yields	0.581***	0.064	0.460***	0.568	0.345	0.026	0.002	−0.795
High fertility rate	0.148**	−0.007	0.182**	−0.404*	0.016	−0.151**	0.249***	0.345
Disease resistance	0.289***	−0.027	0.287**	−0.112	0.324	0.079	−0.081	0.123
Good heat tolerance	0.236**	0.084	0.380***	−0.373	0.633**	−0.086	−0.050	0.084
Easy to handle	−0.040	0.028	0.105	−0.085	0.353*	−0.075	0.024	0.001

*Significant at 10%; **significant at 5%; ***significant at 1%.
FR, free range; SC: semi-confined; CS, confined system; R1, home consumption; R2, cash income; R3, emergency; R4, asset building.

assets (R4) with a utility of 0.594, 0.194 for R3 and a discounting of −0.059 for R1. Similarly, the deductions above applied to the rapid growth rate, small IC body size, good heat tolerance and easy to handle in R2 and the high fertility rate in both R3 and R4. Conversely, utilities for egg yield and disease resistance based on the intended reasons for keeping IC were not different from that of an average farmer since these traits were absolutely important (Table 4).

Table 5 gives the interactions among trait levels for selection and breeding with the farm and farmer characteristics. Only the significant marginal values, which were either negative or positive, were explained. All the negatively significant coefficients indicated that the attribute level represents a reduction to the farmers' utility and the positive significant coefficients were an addition. For cock's traits, good plumage colour and good fighting ability were significant for FR. Heavy body weight and disease resistance were negatively significant for SC. While rapid growth rate, disease resistance and good plumage colour were positive and good fighting ability was negatively significant in CS. Of the seven trait interaction levels for hens, high egg yield and poor hatchability were positive, with a negative significance for disease resistance under FR. At the same time, heavy body weight, disease resistance and good mothering ability were negatively significant for SC. The results also showed that for CS, rapid growth rate and disease resistance were positively significant, but heavy body weight and good mothering ability were negative. It was, however, not possible to do segmentation using good broodiness trait level based on the production systems because of its usefulness.

With the reasons for keeping as segments (Table 5), the traits that were significant for cocks based on R1 were good plumage colour being negative but good fighting ability being positive. Rapid growth rate and good plumage colour were positive and good fighting ability was negatively significant for R2. For R3 rapid growth rate, good plumage colour and good fighting ability were negatively significant but disease resistance was positively significant, whereas for R4 good plumage colour and good fighting ability were both positively significant. Using

Table 5. Influence of the interactions of levels of traits considered for selection and breeding purposes and the farm and farmer characteristics on the producer preference ratings.

	Production systems			Reasons for keeping IC				Average farmer
	FR	SC	CS	R1	R2	R3	R4	
Cocks								
Heavy body weight	0.186	−0.142***	0.068	−0.153	−0.011	−0.066	0.029	0.350
Rapid growth rate	−0.014	−0.057	0.304***	−0.290	0.424***	−0.155***	0.072	0.168
Disease resistance	0.006	−0.270***	0.188**	−0.050	0.108	0.135***	0.042	0.229
Good plumage colour	0.328***	−0.027	0.254***	−0.419**	0.238*	−0.172***	0.283***	0.094
Good fighting ability	0.236**	0.056	−0.198***	0.612**	−0.213*	−0.447***	0.306***	0.136
Hens								
Rapid growth rate	−0.003	0.021	0.229**	−0.134	0.430***	−0.144**	0.174***	0.081
Heavy body weight	−0.124	−0.167***	−0.206**	0.298	−0.019	−0.029	0.135***	0.043
High egg yield	0.390***	0.031	0.042	−0.140	−0.026	−0.181***	0.212***	0.293
Poor hatchability	0.367***	0.003	−0.082	−0.064	−0.197**	−0.035	0.167***	−0.080
Disease resistance	−0.287***	−0.194***	0.180**	0.192	0.156	−0.001	0.034	0.214
Good broodiness	−0.163	−0.086	0.024	−0.096	0.281**	−0.138**	0.030	0.103
Good mothering ability	−0.046	−0.144**	−0.251***	0.117	−0.189	−0.155***	0.280***	0.474

*Significant at 10%; **significant at 5%; ***significant at 1%.
FR, free range; SC, semi-confined; CS, confined system; R1, home consumption; R2, cash income; R3, emergency; R4, asset building.

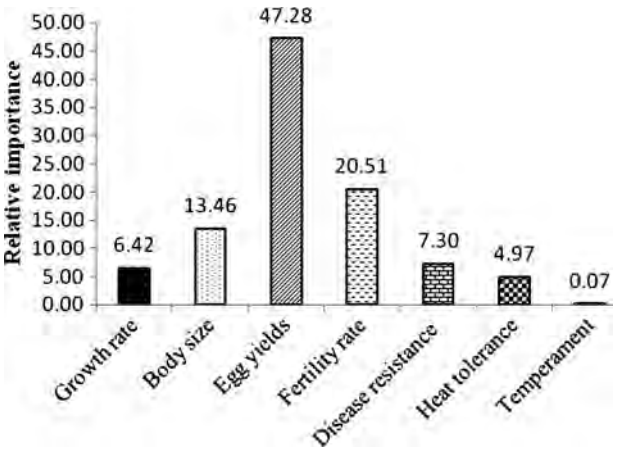

Figure 1. Relative importance for traits perceived to be of primary importance by producers.

the trait "rapid growth rate", for instance, an average farmers' part-worth would be 0.168, while the overall utility after adding the marginal utilities were 0.592 and 0.013 for cocks pertaining to R2 and R3, respectively. This meant that the farmers whose reason for keeping was R2 placed a higher value to this attribute when selecting and breeding. The same analogy applied to all significant trait levels in the various classifications. The utility levels for R1 reason to keep IC were not different from that of a representative farmer since none of the trait levels was significant. Rapid growth rate and good broodiness were positive and hatchability had a negative significance for R2 target group. Furthermore, rapid growth rate, high egg yield, good broodiness and good mothering ability were negatively significant for R3. However, for R4 rapid growth rate, heavy body weight, high egg yield, poor hatchability and good mothering ability were all positively significant. Heavy body weight for cocks and disease resistance for hens were not significant in all the reasons indicating their importance in IC rearing.

Relative importance of attributes

The relative importance scores of the attributes were estimated for all the models and are presented in Figures 1, 2a and b.

In Figure 1, for the traits perceived as of primary importance by producers, the trait egg yield measured in terms of the number of eggs laid per chicken in a year had the highest relative score of 47.28, while temperament had the lowest value of 0.07. All the relative scores add up to 100.

Figures 2a and b are the relative importance of traits considered by farmers for selection and breeding purposes. In Figure 2a, the traits perceived as important for cocks were body weight at sexual maturity with a high score of 35.87, while disease resistance and growth rate were at 23.40 and 17.23, respectively; the lowest score was 9.61 for plumage colour. Conversely, mothering ability scored high for the hen's traits in Figure 2b with a value of 36.81. Body weight at sexual maturity had the lowest score of 3.31.

Culling and selection for superior qualities

Table 6 presents results on the weighted indices for the reasons for culling and selection. The results indicate that there was a reasonable agreement for sale as a motive for culling, which basically implies that farmers do normally sell most of their stock for cash income while doing the selection to obtain the desired stock. This was followed by those culled because of consumption, sickness, fear of disease, low productivity, old age, to reduce the size of the flock for better management and for traditional sacrifices in that order. Unproductive chickens, excess cocks and cockerels accounted for most of consumption and sale. It was observed that the selected breeding cocks and hens were never sold or slaughtered for home consumption until the unproductive old age. Interestingly none of the farmers culled IC for traditional

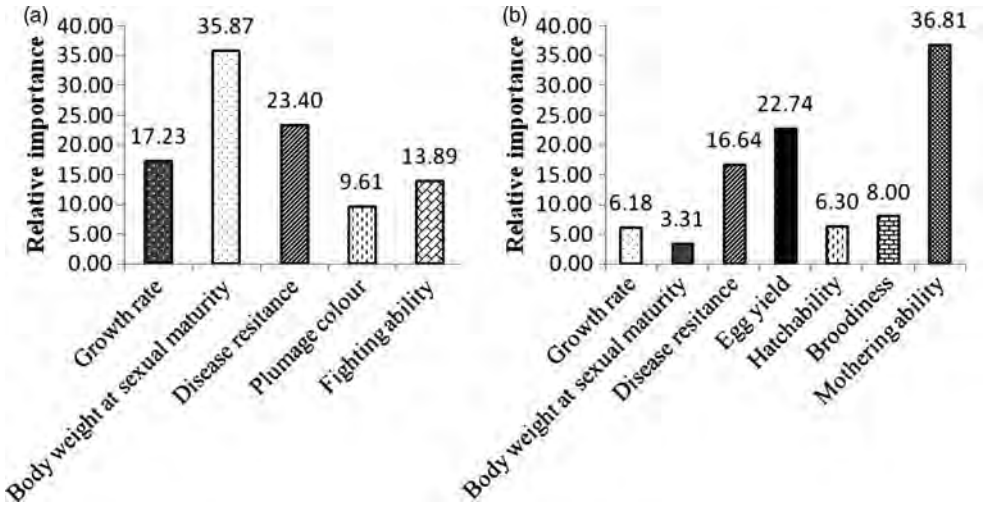

Figure 2. Relative importance for traits of cocks (a) and hens (b) considered important for selection and breeding.

Table 6. Reasons for culling and selection.

Reason	Sum of ranks	Index
Sale	206	0.256
Consumption	186	0.231
Sickness	167	0.207
Fear of disease	100	0.124
Poor productivity	66	0.082
Old age	45	0.056
Large numbers and therefore unable to keep	36	0.045
Traditional sacrifices	0	0.000

sacrifices, indicating that some of the traditions have been abandoned in the areas of study.

Discussion

Main effects of IC trait levels perceived by farmers as most important on ratings

The rapid growth rate, high fertility rate, good heat tolerance and disease resistance are considered important by farmers and are therefore positive and significant in model I. Most of these traits may have a direct or indirect influence on the marketability of chickens. Disease resistance has a positive influence on the productivity of chickens. Rearing of IC is a relevant tool in the eradication of poverty in the rural areas (Ondwassy *et al.*, 2000; Yoo, 2005); therefore, the low level of disease resistance would have significant financial losses as a result of mortalities (Kondombo *et al.*, 2003; Biswas *et al.*, 2006). Heat tolerance is another valuable attribute preferred and should be considered in selection and breeding programmes of ICs, since domestic chicken become easily susceptible to heat or cold environmental stress (Ramnath, Rekha and Sujatha, 2008). Apparently, the naked neck genotype has been identified to be more heat tolerant and disease resistant in the locally existing conditions (Islam and Nishibori, 2009). Conversely, ICs have low performance and survival rate than the exotic breeds under confinement (Tadelle, Alemu and Peters, 2000; Solomon, 2003). This is due to the fact that they are not used to being enclosed and they mainly suffer from paralysis as a result of Marek's disease (Reta *et al.*, 2006).

Small-sized and low-egg-yielding chickens are undesirable. Generally, a large-sized chicken is better than a small-sized one. The farmers' preference would be guided by the reasons for keeping, for instance rearing for eggs, meat production, or dual purpose. The egg yield particularly had the highest relative score with a value of 47.28 for the traits perceived as generally important. As expected, farmers would choose high-egg-yielding chicken to satisfy both commercial and subsistence needs, but would be much influenced by the genotype selected, because of the variations that exist in their egg production potentials (Tadelle, Alemu and Peters, 2000; Grobbelaar, Sutherland and Molalakgotla, 2010). Egg production of IC has been identified as the main reason for keeping (Abdelqader, Wollny and Gauly, 2007) and as a function (Dana *et al.*, 2010). However, the low productivity of IC is partly attributed to the prevailing poor management practices, in particular the lack of proper health care which results in high mortalities, poor nutrition and housing (Mwalusanya *et al.*, 2002; Biswas *et al.*, 2006). Improving these factors would result in greater growth rate and egg production (Kingori, Wachira and Tuitoek, 2010). High fertility rate, on the other hand, would increase hatchability of eggs, therefore enhancing the chances that more chicks survive for subsequent consumption and sale.

Implications of farmers' preference ratings and their relative importance in breeding and selection

While carrying out breeding and selection, farmers evaluate all of the traits that are important to them. These traits are then traded off against one another to obtain more economical and favourable attributes in the long run. This criterion would assist in selecting chicken that meets both the conformity and overall production purpose overtime. For instance, in model II, rapid growth rate, heavy body weight at sexual maturity, resistance to diseases, good fighting ability and good plumage colour are all positive and significant. This shows that farmers are not willing to trade-off high levels of these traits with the lower levels. It further implies that all the selected traits, though having varying utility values, are important for breeding and selection purposes. Moreover, the traits such as growth rate and body weight are economically important when rearing cocks for sale, because heavy cocks would fetch high prices in the market. Even though the local chickens are slow in maturity, selection for faster growth rate is crucial since some of these desirable attributes can be passed on to the other generations. However, maternal effects should be considered if selection to improve the genetic potential of IC is carried out at early ages (Norris and Ngambi, 2006). In broiler chicken, selection for body weight and growth has been outstandingly improved, resulting in a negative influence on their reproductive fitness (Rauw *et al.*, 1998; Havenstein, Ferket and Qureshi, 2003). Nevertheless, slight improvements in growth, body weight and greater survivability would have little influence on the ICs' reproductive performance unlike in the highly selected commercial lines.

Using the systems of production to compare the preferred traits, an attribute such as the fighting ability would be more appropriate in the FR system, where there is little control of the flock, and least desirable under confinement. Farmers in most cases keep one breeding cock within a flock, additional cocks and cockerels are kept for either consumption or for sale depending on their goals. Fighting ability as an economically important trait is important especially in cases where farmers keep large flocks with many cocks for different purposes. Uncontrolled breeding is common in the rural areas

under the FR system of production. In the process of foraging or scavenging, the free ranging ICs meet other flocks at the village; nevertheless, successful mating would require the presence of a strong desirable breeding cock. The control of the flock of the dominant cock often results from an initial antagonistic interaction with the rest of the cocks. In such a scenario, preference to this trait is then justifiable. Many studies have been able to demonstrate a clear relation of male mating and reproductive success to male dominance (Guhl, 1950; Cheng and Burns, 1988). It has also been observed that cocks' natural aggressiveness and fighting are linked to the dominance behaviour or territorial control (Queiroz and Cromberg, 2006). This means that this trait can also be translated as desirable for those whose goal is rearing fighting cocks for entertainment purposes where the physically fitness and training are a prerequisite, although this activity is only practised in some parts of the country, especially the western region of Kenya. In this case, the usefulness of this trait is twofold.

Survivability of the IC depends on its ability to hide or escape from the predators under the predominant FR system of production in the rural areas. The ability to camouflage in the surrounding environment is determined by the plumage colour. White plumage colour was least desirable to the farmers and the ICs with this kind of plumage were evidently few within the households. Farmers alleged that white chickens were easily preyed on by both aerial and terrestrial predators. Biswas *et al.* (2006) recognized that predators among others are the major causes of mortalities in local chickens. Furthermore, the present study observes that the market value of cocks can also be attributed to the good plumage colour. This is important in influencing the preferences of buyers, who in turn would be willing to pay more. This trait was used auspiciously by traders to differentiate the cocks' prices from the primary to the terminal markets in the study areas. Conversely, in studies in other parts of Africa, ICs with white plumage were preferred for use in fulfilling traditional rites (Swatson, Nsahlai and Byebwa, 2001), and had some beneficial significance for peace (Faustin *et al.*, 2010).

In model III, good mothering ability, high egg yield, good broodiness and rapid growth rate are the traits that had positive path-worth values. This means that the IC farmers would derive a high utility from these traits for their breeding and selection stock. For example, McAinsh and Kristensen (2004) found out that some of these traits, including survival of various age groups, full-grown weights, as well as some decision parameters like farmers' need for meat consumption, slaughtering and the age of disposing chickens, if improved, can have the largest impact on output. In this study, producers would prefer high-egg-producing ICs in their flock. This was also recognized as an important selection criterion adopted by farmers in northern Jordan (Abdelqader, Wollny and Gauly, 2007). However, this process can be achieved traditionally by monitoring the number of eggs and the laying rate (Menge, Kosgey and Kahi, 2005). Consequently, it is essential to develop rapid and accurate selection methods since the existing breeding programmes may take a long time (Yang *et al.*, 2008). This can be partly achieved by training and encouraging IC farmers to keep vital production records in order to provide appropriate information that facilitates the selection of the best performing IC at the farm level, which is not often done.

Disease is a major problem in poultry production under all the systems of production and more seriously under the FR. Low levels of disease resistance in IC mean that in events of an outbreak, colossal losses would be anticipated and only the healthiest birds may remain on the farm; they can then be used as breeding stock. More ICs will be bought from the market or exchanged in order to sustain production. Producers would therefore prefer ICs with some level of disease resistance. This is apparent by the positive utility to disease resistance for both cocks and hens with some reasonable degrees of relative scores. In other studies, disease has also been identified as the greatest constraint on rural poultry development (Aini, 1990; Gueye, 2002; Mack, Hoffmann and Otte, 2005). However, some diseases such as Newcastle, which often results in severe mortalities, can be controlled by early vaccination (Ondwasy, Wesonga & Okitoi, 2006); this can be achieved with the assistance of the government extension agents and the non-governmental organizations (MoLD, 2006). However, in most cases, farmers are not aware of this possibility. From the farmers' group discussions in the study area, disease prevention and cure were seen as an important aspect of conservation of ICs. Interestingly, apart from the use of ethno-veterinary drugs, some farmers asserted that they had used cow milk effectively to cure some of the prevalent diseases. This claim, however, has not been documented or scientifically proven.

Good broodiness had a positive utility and a relative score of 8.0 percent for hens. This implies that even though some utility can be derived from this trait, a broody chicken in most cases would be a poor layer and preference to this attribute would be low, but still considerable. Moreover, low production of ICs ready for slaughter or sale is often a result of few clutches per hen per year with long brooding periods (McAinsh *et al.*, 2004). But this loss is partially compensated by a higher laying rate during the non-broody period as observed by Jiang, Chen and Geng (2010). Conversely, the survivability of the broody hens' chicks is usually low which was mainly attributed to diseases and loss to predators in the smallholder system (Biswas *et al.*, 2008). While low number of chicks implies low flock productivity, the situation can be improved by good management practices such as brooding encouragement, improving housing facilities and minimizing predation (Mtileni *et al.*, 2009). In our study, farmers mostly rely on natural brooding to produce chicks. This is usually achieved by choosing a large broody hen to sit on and effectively cover all the eggs

comparable to what is described in Sonaiya and Swan (2004). However, a few of them were able to access the shared artificial brooders from the farmer groups which were either bought or provided by the non-governmental organizations for a period of time on rotational basis. Consequently, these brooders were useful since it reduced the likelihood of hens' over brooding which producers find a problem in egg production. Broody hens were then stimulated to resume laying using traditional methods such as dipping them in cold water and hanging them upside down among many others. Similar methods were reported in Tadelle *et al.* (2003b). In this case, the preference of a broody chicken is necessary as long as it does not become excessively broody. This trait can be utilized effectively when we have chickens that do not conveniently go broody within the flock. This assertion is clearly supported by Abdelqader, Wollny and Gauly (2008), who in their study observed that few hens laid eggs continuously throughout the year. It can also be important in serial hatching where chickens are given eggs to sit on continuously for two or more times by removing chicks every time they hatch and replacing them with new eggs as explained by Ondwasy, Wesonga and Okitoi (2006).

Mothering ability had the highest score and a positive utility among all the traits, indicating its importance to the IC farmers. A hen with good mothering ability can increase the survival chance of naturally hatched chicks. Similarly, this trait was considered important in selecting female ICs in Thailand (FAO, 2009), and was secondly preferred after egg production by farmers in Jordan (Abdelqader, Wollny and Gauly, 2007). In addition, the ICs with good mothering ability can also be used as foster mothers (Kitalyi, 1998). Conversely, the traits that farmers valued least are heavy weight at sexual maturity and poor hatchability. This means that there was some partial preference to hens with minimum body weight at sexual maturity, since lighter birds lay more eggs. The smaller size is also necessary to reduce feed requirements and increase feed efficiency in the FR system (Olawunmi, Salako and Afuwape, 2008). Farmers were, however, indifferent to poor hatchability; this trait is hence not significant. Subsequently, it had low relative importance as a breeding trait. This implies that farmers would standardize the number of eggs per hen to achieve higher hatchability. Sonaiya and Swan (2004) acknowledged that hatchability often declines with more than 10 eggs, which basically depends on the size of the hen. This might also be the reason for the low relative value for the egg yield, as compared with the results in Figure 1.

Conclusions

In the present study, traits of economic importance preferred by the indigenous chicken farmers have been identified using conjoint analysis. The relative scores were calculated to determine the traits that would have the greatest influence on the farmers' IC production or rearing decisions. Disease resistance was among the highly preferred traits for both breeding cocks and hens. Mothering ability and egg yield were important for keeping breeding hens. Body weight at sexual maturity, resistance to diseases and growth rate were the most important traits preferred for cocks. Using the traits identified, without making any major changes to the current low-input production systems, the local genotypes can be selected for more productivity and optimal performance while retaining their diversity and adaptability. This would directly improve the livelihoods of the poor rural IC farmers in the long run. The results have also clearly highlighted the need to consider the farmers' preferences in future improvements of ICs. In particular, the outcome is important in the selection and development of breeding schemes.

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Breeding and conservation programmes for Sahiwal cattle genetic resources in the tropics: a review

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Summary
Studies on Sahiwal cattle genetic resources in the tropics have mainly concentrated on evaluating their performance levels, with only a few published reports describing the breed characteristics. The aim of this study was to critically examine the existing breeding and conservation programmes for Sahiwal cattle in the tropics, focusing on Pakistan, India and Kenya as the core regions of development. The study was based on review of both published and unpublished literature highlighting shortcomings and strengths in the existing strategies, and opportunities for improvement and conservation. The Sahiwal breed is utilized for dairy and beef production under smallholder dairy, pastoral extensive and ranching production systems, both as pure-breds or cross-breds. The necessary components to strengthen the breeding programmes such as performance recording, genetic evaluation and artificial insemination (AI) facilities exist to differing degrees. Breeding and conservation efforts benefit from the technical and financial support from government research institutions which also provide incentives to enhance participation in the programmes. However, breeding goals are rather informal and only defined in terms of high-production levels with functional traits largely ignored. There is need for participatory identification of breeding and production goals, and structured cooperation of the small herds, so as to accommodate the specific contributions of the breed in future breeding and conservation programmes.

Keywords: *Breeding programme, Conservation, Sahiwal cattle, Tropics*

Résumé
Les études sur les ressources génétiques des bovins Sahiwal aux tropiques se sont principalement concentrées sur l'évaluation de leurs niveaux de performance et uniquement quelques rares publications ont décrit les caractéristiques de la race. Cette étude a pour but l'analyse critique des programmes de sélection et de conservation existants qui concernent les bovins Sahiwal aux tropiques, avec une attention particulière pour le Pakistan, l'Inde et le Kenya en tant que régions principales de développement. L'étude se base sur l'examen des documents publiés et non publiés qui mettent en évidence les lacunes et les points forts des stratégies actuelles, ainsi que les opportunités d'amélioration et de conservation. La race Sahiwal, pure ou croisée, est utilisée pour la production laitière et de viande dans les petites exploitations de production laitière, dans les systèmes de production agropastorale extensive et de pâturage extensif. Les éléments nécessaires pour renforcer le programme de sélection, comme le contrôle des performances, l'évaluation génétique et les installations pour l'insémination artificielle, sont en place à des stades différents. Les initiatives de sélection et de conservation bénéficient de l'appui technique et financier des institutions gouvernementales de recherche qui fournissent également des mesures d'incitation pour accroître la participation aux programmes. Cependant, les objectifs de sélection sont plutôt informels et uniquement définis selon des niveaux de production élevée tandis que les caractères fonctionnels sont largement ignorés. Il est nécessaire d'identifier de façon participative les objectifs de sélection et de production, et une coopération structurée des petits troupeaux pour que les contributions spécifiques de la race soient incluses aux prochains programmes de sélection et de conservation.

Mots-clés: *Programme de sélection, conservation, bovins Sahiwal, tropiques*

Resumen
Los estudios sobre los recursos genéticos pertenecientes al ganado Sahiwal en el trópico han estado centrados, principalmente, en la evaluación de sus niveles de rendimiento, con muy pocos trabajos publicados describiendo las características de la raza. El objetivo de este estudio ha sido examinar de forma crítica los programas de mejora y conservación existentes para el ganado Sahiwal en el trópico, centrados en Pakistán, India y Kenia, como las regiones centrales de desarrollo. El estudio se ha basado en la revisión del material publicado y no publicado hasta el momento, destacando las deficiencias y fortalezas en las estrategias existentes y las oportunidades de mejora y conservación. La raza Sahiwal se utiliza para la producción de leche y carne por parte de pequeños productores de leche y

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sistemas de producción de cría extensiva, tanto para animales de raza pura como para animales cruzados. Los componentes necesarios para fortalecer el programa de mejora, tales como los registros de rendimiento, las evaluaciones genéticas y las instalaciones para la inseminación artificial existen para diferenciar los distintos grados. Los esfuerzos en mejora y conservación se benefician del apoyo técnico y financiero de instituciones gubernamentales de investigación, que también proporcionan incentivos para aumentar la participación en tales programas. Sin embargo, los objetivos de mejora son más bien informales y sólo definidos en términos de altos niveles de producción, con las características funcionales ignoradas en gran medida. Existe la necesidad de llevar a cabo una identificación participativa de las metas relacionadas con la mejora y con la producción, así como una cooperación estructurada de los rebaños de pequeño tamaño, a fin de dar cabida a las aportaciones específicas de la raza en los futuros programas de mejora y conservación.

Palabras clave: *Programa de mejora, conservación, ganado Sahiwal, Trópicos*

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Introduction

The Sahiwal cattle belong to a group of large Zebu breeds that are generally classified as dual purpose. The breed is mainly utilized for milk and beef production because it has relatively high milk production and growth performance compared with other Zebu cattle breeds (Trail and Gregory, 1981; Muhuyi, Lokwaleput and Sinkeet, 1999; Joshi, Singh and Gandhi, 2001). The Sahiwal breed has evolved in harsh and diverse tropical environments and carries unique adaptive capabilities that make it relatively competitive in terms of production and adaptation under low-input production systems (Muhuyi, 1997; Philipsson, 1999; Joshi, Singh and Gandhi, 2001). The breed has been spreading to various tropical regions and comes second to the Brahman in terms of distribution among the Zebu breeds of South Asian ancestry (FAO, 1992; Joshi, Singh and Gandhi, 2001; Mulindwa, Ssewannyana, Kifaro, 2006; Hatungumukama and Detilleux, 2009). Previous studies on the Sahiwal cattle breed have mainly focused on performance evaluation. Furthermore the existing reports mainly describe the breed characteristics, highlighting only the desirable attributes. There is no literature study that collates and critically examines information from the various countries on the strengths and shortcomings in the existing breeding and conservation strategies. This study was therefore designed to critically examine breeding and conservations programmes of Sahiwal cattle genetic resources in the tropics, focusing on Pakistan, India and Kenya as locations of main development and distribution. The purpose of this study was to identify shortcomings and strengths in the existing strategies, and opportunities for genetic improvement and conservation. In this paper, the term Sahiwal genetic resources is used to refer to both Sahiwal and its crosses with other cattle breeds.

Study methodology

This study was based on review of both published and unpublished literature concerning Sahiwal cattle breeding and conservation programmes in the tropics. The review mainly focuses on the weaknesses and strengths of existing programmes, and identified opportunities that could enhance breed improvement, utilization and conservation. Information was sourced from journal articles, project and institutional reports, and discussions with key resource persons. Specific information on use values and performance of Sahiwal cattle is highlighted. Breeding and conservation programmes in Pakistan, India and Kenya are specifically described, with emphasis on within country improvement and conservation strategies. A general discussion is dedicated to identifying some of the strengths and opportunities within country strategies that would enhance sustainable utilization and conservation efforts. It should be noted, however, that this review might not have captured all other breeding and conservation programmes for the Sahiwal breed in the tropics. This would be expected because breeding and conservation programmes may be existing in other regions but seldom reported through the conventional avenues. The difficult in finding published information on livestock breeding programmes described in sufficient detail in the tropics has been acknowledged (Rege *et al.*, 2001; Kahi, Rewe and Kosgey, 2005).

Breed description, uses and performance of Sahiwal cattle in the tropics

The Sahiwal breed is commonly of a reddish dun colour with more of a dark-brownish colour around the hump and neck (Muhuyi, Lokwaleput and Sinkeet, 1999; Ojango, Malmfors and Okeyo, 2006). In males, the colour darkens towards the extremities (i.e. head, legs and tails), while females maintain the reddish coat colour. Sahiwals have a characteristic large, long and drooping ears; skin coat is generally smooth and shiny especially during hot-weather conditions. Males attain a wither height of about 140 cm with a well-developed thoracic hump that is normally perpendicular to the backline (Muhuyi, Lokwaleput and Sinkeet, 1999). Females are about 120

cm at maturity, they have large udders compared with other *Bos indicus* breeds and large unevenly distributed teats. Compared with other Zebu cattle breeds, Sahiwal are generally docile and of low temperament, characteristics that allow them to be milked in the absence of calf (Kimenye, 1978).

Some of the traits description and their corresponding attributes that have traditionally been considered important for Sahiwal cattle in the tropics are summarized in Table 1, whereas Table 2 shows performance estimates of various production and reproductive traits of Sahiwal cattle and other selected Zebu cattle breeds in the tropics. Sahiwal cattle generally possess attributes and characteristics that make them relatively competitive under highly challenging low-input production systems in the tropics. However, it is important to note that there are other indigenous Zebu cattle breeds that are relatively more adapted to specific production systems, a fact that demonstrates clear trade-offs between the Sahiwal genetic resources and such breeds with regard to productivity and adaptability. For example, in a recent study on the role of Sahiwal genetic resources in pastoral production systems in Kenya, Roessler, Ilatsia and Valle Zárate (2010) and Ilatsia *et al.* (2010) reported that pastoralists rated Sahiwal genetic resources highly with regard to production and fertility traits but were more apprehensive of their disease, parasite and drought tolerance relative to the local East African Zebu breed. Such trade-offs need to be taken into account when making consideration of the various options for designing breeding programmes, because cattle keepers in low-input production systems prefer mixed-breed herds, attaching to each breed involved different trait profiles depending on their desired production objectives (Valle Zárate, 1996). Thus, the future breed planning and organization should take a comprehensive account of the breed attributes that capture the full array of contributions of Sahiwal genetic resources to producers' livelihoods.

According to the livestock sector strategy of the Government of Punjab and the Agricultural Census Organization in Pakistan, Sahiwal genetic resources are among the leading sources of milk in Pakistan, coming second to buffaloes in domestic milk supply in Punjab province which is home to nearly half of the Pakistan population (Agricultural Census Organisation, 2006; Khan *et al.*, 2008; Government of Punjab, 2010). In Kenya, Sahiwal genetic resources are mainly kept by pastoralists, private and government ranches, and by a few smallholder dairy farmers for domestic milk production and revenue generation through sale of live animals and surplus milk (Muhuyi, 1997; Bebe *et al.*, 2003; Roessler, Ilatsia and Valle Zárate, 2010). Sahiwal bulls and semen have been exported from Kenya to several other East and Central African countries for crossing with various local Zebu breeds for milk production as well as provision of farm power (KARI, 2004; Mulindwa, Ssewannyana, Kifaro, 2006; Hatungumukama and Detilleux, 2009). In India, Sahiwal and their crosses are raised by smallholder farmers, government and private nucleus farms mainly for dairy production (Joshi, Singh and Gandhi, 2001; Singh, Kumar and Varma, 2005). Previous organized cross-breeding programmes involving the Sahiwal and mainly European breeds have been used to develop synthetic breeds in India. For example, the Karan Swiss and Frieswal have been developed through several years of crossing the Sahiwal to the Brown Swiss and Friesian breeds, respectively (Singh and Gurnani, 2004; Gaur *et al.*, 2006; NDRI, 2007). The synthetic breeds have shown the advantage of combining the high-production levels of the European breeds and adaptation of the Sahiwal on a sustainable basis for dairy production under smallholder production conditions (Kahi *et al.*, 2000; Singh and Gurnani, 2004; Gaur *et al.*, 2006).

Performance and genetic parameter estimates for various production and reproductive traits of Sahiwal cattle are

Table 1. Production and functional traits of Sahiwal cattle and some of their related attributes.

Traits	Important attributes	Reference
Growth and meat quality	Low birth weights, high pre- and post-weaning gain, well-marbled meat with a very high meat-to-bone ratio, large loin muscle area, flat and wide. Highly developed rump for meat deposition, high live weight.	Khan *et al.* (1999), Muhuyi (1997), Mwandotto (1985), Trail and Gregory (1981)
Milk yield	Relatively high milk yield and lactation length, persistence, high butter fat, protein, and solid non-fat content, large and well-attached udder.	Kimenye (1978), Muhuyi (1997), Dahlin *et al.* (1998), Joshi, Singh and Gandhi, 2001
Reproduction	High calving rate under natural mating, calving ease (few dystocia incidences), early onset of puberty, high weaning rate, short CI under natural mating.	Khan *et al.* (1999), KARI (2004), RCCSC (2007)
Temperament	Good milking ability in the absence of calf, ease of handling, good mothering ability.	Muhuyi, Lokwaleput and Sinkeet (1999), KARI (2004)
Equal to seven adaptability	Disease tolerance, parasite tolerance, long productive life, ability to dissipate heat, smooth and shiny skin coat to reflect heat, long and pendulous ears as fly and insect swatters, loose and pliable skin to dislodge insects and ticks (extra layer of muscle tissue just under the skin which enables them to shake their skin to remove or discourage parasites)	Kimenye (1978); Muhuyi (1997), Dahlin *et al.* (1998), Joshi, Singh and Gandhi (2001)
Feed utilization efficiency	Conversion of low-quality feed into milk and beef, low maintenance requirement, ability to utilize poor quality pastures, ability to cope with feed and water scarcity, more efficient digestion	Kimenye (1978), Singh and Kumar (1997)

Table 2. Performance estimates for production and reproductive traits of Sahiwal cattle in the tropics.

Trait[a]	Breed	Country	Mean	No. of records	References
LMY (kg)	Sahiwal	Pakistan	1 395	9 382	Dahlin *et al.* (1998)
	Sahiwal	Pakistan	1 537	5 697	Zafar, Ahmad and Rehman (2008)
	Sahiwal	Pakistan	1 547	3 434	Rehman, Ahmad and Shafiq (2006)
	Sahiwal	Pakistan	1 475	2 039	Bajwa *et al.* (2002)
	Sahiwal	Kenya	1 370	6 365	Ilatsia *et al.* (2007)
	Hariana	India	1 081	601	Dalal, Rathi and Raheja (2002)
	Red Sindhi	Pakistan	1 531	485	Mustafa *et al.* (2002)
305 MY (kg)	Sahiwal	Kenya	1 663	–	Rege, Lomole and Wakhungu (1992)
	Sahiwal	Pakistan	1 363	9 341	Dahlin *et al.* (1998)
	Sahiwal	India	1 760	1 887	Singh and Nagarcenkar (1997)
	Sahiwal	India	1 504	1 367	Banik and Gandhi (2006)
LL (days)	Sahiwal	Pakistan	262	5 697	Zafar, Ahmad and Rehman (2008)
	Sahiwal	India	288	1 887	Singh and Nagarcenkar (1997)
	Sahiwal	Pakistan	268	3 434	Rehman, Ahmad and Shafiq (2006)
	Hariana	India	268	601	Dalal, Rathi and Raheja (2002)
	Red Sindhi	Pakistan	277	485	Mustafa *et al.* (2002)
	Sahiwal	Kenya	278	6 324	Ilatsia *et al.* (2007)
BWT (kg)	Sahiwal	Kenya	22.9	121	Mwandotto (1994)
	Sahiwal	Pakistan	21.6	3 299	Khan *et al.* (1999)
	Sahiwal	Kenya	21.9	5 681	Ilatsia *et al.* (2011)
WWT (kg)	Sahiwal	Kenya	170	187	Trail and Gregory (1981)
CI (days)	Sahiwal	Pakistan	465	3 545	Khan *et al.* (1999)
	Sahiwal	Pakistan	437	4 461	Zafar, Ahmad and Rehman (2008)
	Sahiwal	Kenya	468	4 441	Ilatsia *et al.* (2007)
	Hariana	India	479	601	Dalal, Rathi and Raheja (2002)
NSC	Sahiwal	Kenya	2.1	7 211	Ilatsia *et al.* (2007)
AFC (days)	Sahiwal	Pakistan	1 323	4 213	Khan *et al.* (1999)
	Sahiwal	Kenya	1 347	2 894	Ilatsia *et al.* (2007)
	Hariana	India	1 443	601	Dalal, Rathi and Raheja (2002)

[a]LL, lactation length; LMY, lactation milk yield; 305 MY, 305 day adjusted milk yield; CI, calving interval; AFC, age at first calving; NSC, number of services per conception; BWT, birth weight; WWT, weaning weight.

presented in Tables 2 and 3, respectively. Differences in performance estimates reflect diversity in the gene pools and influence of environmental conditions and production circumstances. Most of these studies were, however, based on data collected from institutional herds, where production conditions might be quite different from the commercial herds. Furthermore, datasets used in the studies were very limited (Table 2), a fact that could cast doubt on the accuracy and reliability of some of the estimates. However, lack of proper recording systems is widely acknowledged as a major challenge in achieving comprehensive performance evaluation in developing countries (Wasike *et al.*, 2011). Slow and undesirable genetic progress has been reported in the breeding goal traits of Sahiwal cattle in the tropics despite selection emphasis on these traits (Dahlin *et al.*, 1998; Khan *et al.*, 1999; Rehman, Ahmad and Shafiq, 2006; Ilatsia *et al.*, 2007). This has been attributed to low selection intensities within the small herds, poor production conditions and high mortalities, inappropriate evaluation procedures and inbreeding depression that may emasculate genetic potential of breeding animals. Inbreeding depression has been reported on some performance traits in stationed maintained Sahiwal cattle populations in Kenya (Rege and Wakhungu, 1992) and Pakistan (Iaved, Mohiuddin and Abdullah, 2001).

Breeding and conservation programmes

Sahiwal genetic resources are distributed in 27 countries in Asia, Africa and the Caribbean (Joshi, Singh and Gandhi, 2001; FAO, 2007). Pakistan, India and Kenya are endowed with the majority of pure-bred Sahiwal cattle and have actively been involved in breeding and conservation programmes. This section will therefore focus on documented breeding and conservation programmes in these three countries. It should be noted, however, that other programmes might have been developed in other regions but have not been reported.

Pakistan

The Sahiwal breed originated in the arid subtropical Indus region of the Punjab province (Dahlin *et al.*, 1995). It was raised in nomadic pastoral systems by the indigenous people for dairy production. However, increased irrigation activities in this region in the 1910s displaced the Sahiwal breed, as farming communities preferred Hissar and Haryiana breeds for draft power (RCCSC, 2007). Pakistan has a national database for various livestock species and breeds; however, there are huge disparities in reported population figures for the Sahiwal cattle breed. According to the country report submitted to the FAO,

Table 3. Heritability estimates for productive and functional traits of Sahiwal cattle in the tropics.

Trait[a]	Genetic parameters					
	Heritability				Model[b]	Reference
	Lactation					
	1	2	3			
LMY	0.32	0.45	0.41	0.16	AM	Ilatsia *et al.* (2007)
	0.15	0.12	0.17	0.17	AM	Dahlin *et al.* (1998)
	0.18				AM	Choudhary *et al.* (2003)
				0.15	AM	Bajwa *et al.* (2002)
	0.27			0.32	AM	Kumar, Gandhi and Haile (2009)
	0.17	0.15	0.20		AM	Dahlin *et al.* (1998)
305MY	0.14	0.11	0.15	0.17	UAM	Dahlin *et al.* (1998)
	0.16	0.14	0.22		MAM	Dahlin *et al.* (1998)
				0.36	SM	Rege, Lomole and Wakhungu (1992)
	0.35	0.47	0.31		PHS	Kimenye (1978)
LL	0.26	0.31	0.34	0.07	AM	Ilatsia *et al.* (2007)
	0.17	0.09	0.11	0.15	AM	Dahlin *et al.* (1998)
	0.14	0.14	0.17		AM	Dahlin *et al.* (1998)
	0.13				AM	Choudhary *et al.* (2003)
	0.25			0.27	PHS	Singh and Nagarcenkar (1997)
CI	0.02	0.03	0.06	0.03	AM	Ilatsia *et al.* (2007)
	0.08			0.15	SM	Rege, Lomole and Wakhungu (1992)
	0.07	0.04	0.05		AM	Khan *et al.* (1999)
	0.06	0.05	0.03		AM	Khan *et al.* (1999)
AFC				0.04	AM	Ilatsia *et al.* (2007)
				0.12	AM	Khan *et al.* (1999)
				0.29	SM	Rege, Lomole and Wakhungu (1992)
NSC				0.01	AM	Ilatsia *et al.* (2007)
				0.02	SM	Rege, Lomole and Wakhungu (1992)
BW				0.35	SM	Rege, Lomole and Wakhungu (1992)
				0.21	AMM	Khan *et al.* (1999)
				0.23	AMM	Ilatsia *et al.* (2011)
YW				0.16	PHS	Mwandotto (1994)
				0.14	AMM	Ilatsia *et al.* (2011)
27WT				0.31	PHS	Mwandotto (1994)

[a]LL, lactation length; LMY, lactation milk yield; 305 MY, 305 day adjusted milk yield; CI, calving interval; AFC, age at first calving; NSC, number of services per conception; BW, birth weight; YW, yearling weight; 27MWT, weight at 27 months.
[b]UAM, univariate animal model; MAM, multivariate animal model; PHS, paternal half-sib correlation; SM, sire model; ICC, intra-class correlation; AMM, animal-maternal mode.

Pakistan has estimated 0.35 million Sahiwal cattle (Government of Pakistan, 2003). This estimate is far below that of the recent livestock population census published by the Agriculture Census Organization which indicates a population of approximately 2.7 million Sahiwal cattle, out of which approximately 80% (2.0 million) are found in the Punjab state province alone (Agricultural Census Organisation, 2006). The reasons underlying these huge discrepancies in the estimates cannot be discerned; however, it is possible that both estimates could have either included or excluded some non-descript breed types and other Sahiwal derivatives. It is possible that the population census results could include figures arising from inaccuracies and inconsistencies on the farmer's and enumerator's side in breed identification especially where documented pedigree information is lacking.

Strategic breeding and conservation programmes have been operational in Pakistan for the last three decades. This could be traced to previous collaborative research programmes involving the FAO, the Pakistan Research Council and the Swedish University of Agricultural Sciences which recommended the establishment of a genetic improvement and conservation programme for the breed in Punjab (FAO, 1992; Dahlin *et al.*, 1995). This was in recognition of the economic contribution of the breed to rural livelihoods, as well as the threat posed to the future of the breed due to indiscriminate cross-breeding and changes in agricultural systems. This initiative culminated in the recent establishment of the Research Centre for Conservation of Sahiwal Cattle (RCCSC) by the Punjab state government (RCCSC, 2007). The RCCSC has the statutory mandate to register Sahiwal cattle, carry out performance recording and genetic evaluation and to conduct strategic research, in collaboration with national and international research organizations, for genetic improvement and conservation of the breed. Currently, the centre has 24 sub-centres in Punjab which host more than 11 000 registered breeding cows. It also provides artificial insemination (AI) and extension services, and coordinates various disease and parasite control programmes as incentives to Sahiwal producers to participate in the breeding and conservation programmes (RCCSC, 2007). The livestock sector strategy for the government of Punjab state has also prioritized the Sahiwal cattle breed among other indigenous livestock breeds for further genetic improvement and conservation (Government of Punjab, 2010).

Pure breeding is mainly implemented within government and private farms (Dahlin *et al.*, 1998; Khan *et al.*, 1999; Bajwa *et al.*, 2002; Bhatti *et al.*, 2007). The breeding programme depicts an open nucleus breeding system where the RCCSC-coordinated nucleus herds are the main source of breeding animals for other medium and smallholder livestock farms (RCCSC, 2007). Transfer of genetic superiority is mainly realized through AI where superiority of candidate breeding bulls for milk production is evaluated based on a progeny testing (PT) programme (RCCSC, 2007). Multiple ovulation and embryo transfer (MOET) is used to enhance reproductive rates of promising breeding cows (RCCSC, 2007). The RCCSC herds and other private herds form *in situ* conservation units. These farms are also the source of semen and embryos which are frozen and stored for future use.

Indiscriminate crossing remains a major challenge to conservation of the Sahiwal cattle breed in Pakistan (FAO,

1992; Dahlin *et al.*, 1995; Government of Pakistan, 2003). To forestall this, the Pakistan government has formulated breeding policies and regulations that prohibit crossing of the Sahiwal cattle with exotic dairy cattle breeds (Government of Pakistan, 2003), but allows cross-breeding of non-descript populations with exotics breeds. However, enforcement of these regulations has not been fully achieved because of lack of clear mechanisms for their implementation. This could be because breeding and mating decisions are made by individual farmers targeting at the best genetic solution for their farm, which might not always coincide with conservation purposes, unless incentives are given. Further, it may be difficult for farmers to discriminate among which cattle breeds to use in crossing. The net consequence has been that illicit cross-breeding is further predominating leading to erosion of Sahiwal cattle genetic resources.

Both private and government stakeholders are involved in the breeding programme at various levels. However, our study did not find evidence of the technical efficiency, in terms of economic and genetic sustainability, of the existing breeding programme organization. Furthermore, formal breeding goals that reflect the production objectives and breeding aims of the various Sahiwal producers are not documented notwithstanding that Sahiwal genetic resources play different roles alongside other cattle breeds. In addition, the existing breeding programme prioritizes lactation performance and fertility (as a proxy for adaptation) without clear evidence of how other important functional attributes are accounted for.

Nonetheless, the RCCSC could be regarded as a model conservation programme for the Sahiwal breed in the tropics where both human and financial capital has been concentrated to enhance breed conservation and utilization. The expertise at the RCCSC, together with other collaborating institutions provides a platform for consolidating efforts towards developing appropriate breeding schemes involving the various producers. The active involvement of the farmers and private farms in the genetic improvement and conservation programme also provides an opportunity to set up a more inclusive breeding programme and organization with improved chances of sustainable success. The active Sahiwal cattle breed Society in Punjab organizes regularly exhibitions aimed at promoting the breed among producers (RCCSC, 2007).

India

Unlike in Pakistan, our study did not find a national database indicating the population estimates of Sahiwal cattle in India. Nonetheless, there exist breeding and conservation programmes in the country. A pure breeding programme is implemented in 12 state-owned farms receiving technical support from the National Dairy Research Institute (NDRI) (Joshi, Singh and Gandhi, 2001; NDRI, 2007). The contributions of the NDRI in the breeding programme are similar to those carried out by the RCCSC in Pakistan and mainly involve coordination of performance recording, genetic evaluation and dissemination of genetic material to the farmers (Joshi, Singh and Gandhi, 2001; NDRI, 2007). The breeding goal mainly focuses on increased milk production. This is achieved through a performance testing programme based on recorded lactation milk yield of daughters of candidate bulls, supported by AI and a MOET programme (NDRI, 2007). There is no evidence of whether adaptation to local production conditions is also considered as an important breeding goal. Furthermore, similar to the case of Pakistan, there was no clear evidence of how the breeding organization involving the governmental herds is planned for sustainable genetic improvement and conservation.

In situ conversation is mainly concentrated in the 12 government maintained herds where less than 2000 breeding animals are hosted (Joshi, Singh and Gandhi, 2001; Government of India, 2003). There are also a few Sahiwal herds maintained on religious basis referred to as 'Gaushalas' given that cattle are sacred in the Hindu religion (Sadana, personal communication). There are two well-maintained 'Gaushalas' at Sirsa in Haryana and Gurudwara in Punjab, each with a herd of approximately 200 Sahiwal cows. Smallholder farmers also keep between 2 and 3 pure Sahiwal cows for milk production (NDRI, 2007). *Ex-situ* conservation involves cryopreservation of frozen semen and embryos in national gene banks maintained by the NDRI.

Unlike in Pakistan where the breeding policy is prohibitive of crossing Sahiwal cattle with other breeds, various state breeding policies and regulations in India encourage cross-breeding of the breed with exotic breeds for dairy production (Government of India, 2003). Ironically, cross-breeding has been acknowledged as a major contributor to depletion of Sahiwal genetic resources in India (Joshi, Singh and Gandhi, 2001). This observation could be related to a lack of clear regulatory and monitoring mechanisms of these cross-breeding programmes especially at the farmer level, a situation that increases the tendency towards unplanned crossing.

Kenya

The history of Sahiwal cattle in Kenya dates back to the early 1930s when breeding bulls were imported from India and Pakistan for upgrading the local Zebu for higher milk production and enhanced growth performance under low-input production conditions (Meyn and Wilkins, 1974; Trail and Gregory, 1981). The promising results of the upgrading programme led to an increase in demand for Sahiwal bulls mainly by the Maasai pastoralists. A decision was taken in 1962 by the government to consolidate breeding activities by collecting the best Sahiwal cows and bulls from various livestock centres to create the National Sahiwal Stud (NSS) (Meyn and Wilkins, 1974). Other private Sahiwal ranches were also established to supplement the NSS (Muhuyi, 1997). Currently, there

are at least 18 ranch herds that host approximately 7 000 pure-bred Sahiwal cattle with about 1 500 breeding cows (KARI, 2004). Just like in India, there exists no national database showing breed-specific population figures. However, some unpublished reports by field livestock extension officers in the pastoral areas estimate the Sahiwal population at 50 000 with about 170 000 Sahiwal × Zebu cross-breds (MOLFD, 2006).

Pure-breeding and cross-breeding programmes are the main genetic improvement strategies for the Sahiwal breed in Kenya. Pure-breeding programmes mainly involve 18 ranches, besides pastoral herds. Genetic gain is generated in the nucleus herds, mainly through male and to a lesser extent female selection; the transfer of genetic progress to the pastoral herds is realized exclusively through breeding bulls (Muhuyi, 1997; Trail and Gregory, 1981). The primary breeding goals of producers are high milk production, large body size, good fertility and adaptation to local production conditions (Roessler, Ilatsia and Valle Zárate, 2010). However, the suitability as well as genetic and economic sustainability of the currently followed and alternatively suggested breeding schemes reflecting producers breeding goals has not been ascertained.

Conservation of Sahiwal genetic resources in Kenya involve both, *in-situ* and *ex-situ* strategies. Government and privately owned nucleus herds act as *in-situ* conservation units that produce breeding animals for the pastoral herds (Muhuyi, 1997). Pastoralist herds also act as *in-situ* conservation units where Sahiwal cattle genetic resources are reared for both subsistence and commercial purposes. *Ex-situ* conservation takes place exclusively through preservation of frozen semen at the Central Artificial Insemination Station from superior bulls at the NSS (KARI, 2004). Unlike in the case of India and Pakistan, there is no national breeding policy in Kenya that governs use and development of specific livestock species and breeds. The yet-to-be-operationalized animal breeding policy recently developed by the Ministry of Livestock Development (MOLD, 2009) describes conservation measures only in general terms and gives broader recommendations with no clear or specific policies accounting for the multiple roles that different livestock species and breeds play under various production systems. Nonetheless, there are strengths in the current set-up that could form a basis for establishment of an expanded and more inclusive breeding programme. For example, all the nucleus herds keep some performance and pedigree records that could be combined to form a basis for a coordinated joint selection programme among the nucleus herds. The NSS is a research facility under the Kenya Agricultural Research Institute. This offers an opportunity for effective mobilization of financial and human resources, and other infrastructure to provide the required technical support in implementation, monitoring and evaluation of the breeding programme. The existence of the Sahiwal Cattle Breed Society also offers an opportunity to enhance more coordinated breeding and husbandry activities involving the various producers. However, the current diversity of organizations and recording systems involved and the lack of co-ordination between them has to be regarded as a weakness, which needs to be overcome.

General discussion

Breeding goals and breeding organization

The success and sustainability of the breeding and conservation programmes for Sahiwal cattle genetic resources reviewed will depend not only on the technical quality of the selection process but also on the structures of the breeding organization and how the producers' desired breeding goals are accounted for. Except for the Kenyan case, this study did not find evidence of participatory definition of breeding goals that incorporate producers' production objectives. The existing breeding goals are either informal and narrow (i.e. based exclusively on production) or largely neglect the functional attributes that have defined the uniqueness of the Sahiwal breed under low-input production systems, by only addressing adaptation indirectly through selection on fertility. For the programmes to remain relevant and sustainable, compatibility with the socio-cultural and economic aspects of the producers needs to be ascertained and incorporated into future breed planning (Valle Zárate and Markemann, 2010). The present rather marginal and mostly informal involvement of producers in the breeding and conservation programmes in each of the three countries might form a basis for their formal incorporation into the organization. Studies on participatory identification of production aims and breeding goals are already underway in Kenya (e.g. Ilatsia *et al.*, 2010; Roessler, Ilatsia and Valle Zárate, 2010); similar or different approaches of farmer participation could be applied in the Indian and Pakistani cases.

The breeding systems reviewed in this study are based on a pyramidal management of the population with the breeders of nucleus herds at the top and participating herds at the lower levels. Performance recording and evaluation are confined in the nucleus herds as a basis for genetic evaluation and selection. However, evaluations are based on data obtained from either single or a few herds (see Table 2) with focus on production parameters while functional traits such as fertility and survival are seldom considered. Future performance evaluation should strive to better co-ordinate existing data sources, extend the traits to be monitored and augment data from the small herds and pastoralists to improve not only data amount and accuracy but also account for possible genotype × environment interactions that might occur when animals are transferred from the stations to the production sector. According to our study, the organization between the various herds and stakeholders is not even, transparent and may require substantial efforts to consider the organizational aspects towards the achievement of optimal economic and genetic success. Professional planning and implementation will be critical

in order to achieve optimal benefits from the breeding programmes and also make them more sustainable (Kahi, Rewe and Kosgey, 2005).

Cross-breeding

The benefits of cross-breeding strategies involving the Sahiwal breed have sometimes been overstated to an extent that improvement of this breed has been synonymous to cross-breeding. Most of the cross-breeding programmes are not systematic, a scenario that is worsened by either lack of proper policies or in the case of their existence, there is lack of clear regulatory and enforcement mechanisms to ensure that such policies achieve the intended purpose. Strategies that support pure-breeding schemes that produce breeding animals to be used in cross-breeding in a systematic way may be most suitable to combine farmers' preferences with the purposes of breed conservation. This would particularly be important in curbing indiscriminate crossing that is largely blamed for rapid depletion of Sahiwal genetic resources in the tropics (FAO, 1992; Dahlin *et al.*, 1995; Joshi, Singh and Gandhi, 2001). Cross-breeding programmes can be carried out in a way that support and not replace pure-breeding programmes. Kahi *et al.* (2000) recommended cross-breeding systems for Kenya which are able to raise animal production from low to intermediate levels rather than programmes optimized for production, which are logistically difficult to implement and economically unsustainable. It would therefore be desirable that the Sahiwal cross-breds are not just evaluated in terms of their on-station performance (e.g. Singh, Kumar and Varma, 2005; Mulindwa, Ssewannyana, Kifaro, 2006; Hatungumukama and Detilleux, 2009), but also on their resilience to physical environmental conditions in which they are to perform and including considerations for breeding organization and compatibility with conservation of the pure-breed. More effective implementation of cross-breeding policies could also be achieved by the use of ear notching or tagging where sanctions or penalties are preferred in cases where such identity marks are tampered with.

Future considerations

There are prospects for the three countries to cooperate in terms of exchange of genetic material and experiences in their Sahiwal breeding programmes. The difference in herd performances across the countries is an indication that there is some variance in the gene pools of the sub-populations which could be exploited through exchange of breeding material, although some of the differences could also be manifestation of different production environments. The active participation of the respective cattle keepers, the national research and training institutions offer an opportunity for the technical staff to share their experiences and contribute to the realization of the programmes by conducting relevant research, monitoring and evaluation. This could also form the basis for a joint analysis of alternative genetic improvement and conservation strategies aimed at better utilization of Sahiwal cattle genetic resources. The cooperation will also be greatly advantageous in the use of shared infrastructure such as animal information systems and in the application of biotechnologies such as AI and MOET in the breeding and conservation programmes. However, there are logistical challenges that need to be addressed in order to realize the full potential of such a scheme. For instance, farmer preferences may differ between the countries and each country might have Sahiwal cattle breed standards on which potential breeding animals are selected and allowed to join their nucleus stock. This was one of the reasons that an initial programme for semen importation from Pakistan into the Kenyan sub-population was suspended in 1992 over concerns of breed conformity and lack of evidence for genetic merit of the bulls (Muhuyi, personal communication). Furthermore, there are differences in the recording schemes among countries which would make direct comparison of bulls' breeding values a bit difficult and therefore the need to have a standardized basic recording system. The full benefits of the MOET could be realized subject to effective genetic evaluation and selection of female candidates for the scheme. There are also concerns about the financial sustainability of a co-ordinated programme, regarding financial support and cost-benefit sharing given the fact that there would be specific issues within individual countries that would be of priority.

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Conservation of animal genetic resources in Europe: overview of the policies, activities, funding and expected benefits of conservation activities

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Summary
This paper reviews the current situation of conservation activities in Europe. It includes an overview of the current situation of the relevant policy measures and related activities, the involvement of the public and private sector, and funding and estimated benefits of these actions. The review is based on the results of a survey conducted within the European National Coordinators for the management of animal genetic resources (AnGR), initiated by the GLOBALDIV project. The objective of this review is to bring to the attention of policy-makers and European Commission the conclusions and recommendations as a contribution to the formulation of future policies. The increasing awareness to the importance of AnGR biodiversity is reflected in the responses to this survey, particularly in the issues related to the cryoconservation activities in the different countries and the discussion on the expected benefits of the implementation of conservation programmes. The concept of biodiversity as a public good has already been accepted by European public and by policy-makers. The additional scope of protection of farm animal biodiversity, as an investment in the future food security, needs to be reflected in the future policies.

Keywords: *in situ conservation, animal genetic resources, ex situ conservation*

Résumé
Cet article est une revue de la situation actuelle des activités de conservation de ressources génétiques animales en Europe. Il inclut la situation actuelle des mesures politiques et des activités relatives, la participation du secteur public et privé, les finances et les avantages prévus de ces actions. La revue est basée sur les résultats d'une enquête chez les coordonnateurs nationaux européens, lancée par le projet GLOBALDIV. L'objectif de cette revue est de porter les conclusions et les recommandations à la connaissance des décideurs politiques et de la Commission européenne pour formuler les politiques futures. L'accroissement de la reconnaissance de l'importance de la biodiversité de ressources génétiques animales est indique dans les réponses, et particulièrement aux questionnes associées aux activités de cryoconservation dans les différents pays et la discussion sur les avantages prévus del'implémentation des programmes de conservation. Le concept de la biodiversité en tant qu'intérêt public a été déjà accepté par le public européen et par des décideurs politiques. La valeur additionnelle de la protection de la biodiversité d'animal, comme une sécurité de nourriture, doit être introduit aux politiques futures.

Mots-clés: *conservation in situ, ressources génétiques animales, conservation ex situ*

Resumen
En este trabajo se lleva a cabo una revisión de las actuales actividades relativas a la conservación en Europa. Contiene una visión general de la situación actual de las medidas políticas pertinentes y las actividades relacionadas, la participación de los sectores público y privado, la financiación y los beneficios esperados de estas acciones. La revisión se basa en los resultados de una encuesta llevada a cabo entre los Coordinadores Nacionales Europeos para la gestión de los recursos zoogenéticos, iniciado por el proyecto GLOBALDIV. El objetivo de esta revisión es llamar la atención de los responsables políticos y la Comisión Europea acerca de las conclusiones y recomendaciones como contribución a la formulación de políticas de cara al futuro. La creciente conciencia sobre la biodiversidad de los recursos zoogenéticos se refleja en los resultados de esta investigación, sobre todo en las cuestiones relacionadas con la crioconservación en los diferentes países y la discusión sobre los beneficios esperados de la implementación de programas de conservación. El concepto de biodiversidad ya ha sido aceptado como un bien público por el ciudadano europeo y los responsables políticos. El ámbito de aplicación adicional para la protección de la biodiversidad de los animales domésticos, como inversión en seguridad alimentaria para el futuro, debe reflejarse en las políticas futuras.

Palabras clave: *conservación in situ, recursos zoogenéticos, conservación ex situ*

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Introduction

The *Global Plan for Action for Animal Genetic Resources* refers to the importance of animal genetic resources (AnGR) for world food security contributing to the livelihoods of over a billion people. General economic development and population growth and mobility in the world has increased demand for livestock products, but has also introduced pressures on the sustainability of rural environments and animal production systems. It is pointed out that a diverse resource base is critical for human survival and well-being, and a contribution to the eradication of hunger. Furthermore AnGR are crucial in adapting to changing socio-economic and environmental conditions, including climate change. The conservation and sustainable use of AnGR, and the fair and equitable sharing of the benefits from their use, are an international concern and the *Global Plan of Action for Animal Genetic Resources* provides, for the first time, an agreed international framework for the sector (FAO, 2007).

The third Strategic Priority Area of the *Global Plan of Action for Animal Genetic Resources* refers to the conservation of AnGR. Conservation involves both the *in vivo* maintenance and management of genetic diversity within the populations of livestock that are actively contributing to the livelihood of their keepers and the nutritional health of the general population, as well as the *in vitro* storage of genetic material that can be used at a later time to increase or introduce diversity into the live populations.

This review paper deals with the issue of the conservation activities in Europe and includes an overview of the current situation of the relevant policy measures and related activities, the involvement of the public and private sector, funding and estimated benefits of these actions.

The results presented are based in a survey carried out within the European National Coordinators for the Management of Farm Animal Genetic Resources (European Regional Focal Point, ERFP). The National Coordinators (NCs) were requested to fill in a specific questionnaire developed for this purpose in the frame of WP4 of the GLOBALDIV project. A set of questions was included regarding the policy measures, the description of the relevant programmes, the level of support and the calculation of support, the breeds involved, the existence of *in vitro* conservation programmes, the research initiatives and the recorded or expected benefits from these activities in economic, social and environmental level. In total, 21 responses were received in the survey that took place in the period from July 2009 until the end of October 2009. Furthermore, to present a more complete view of the current status of the conservation activities in Europe, information from all European countries members of the ERFP has been included in the report, based on the countries' Annual Reports submitted in the 16th ERFP Annual Workshop (Crete, August 2010) (www.rfp-europe.org).

Historical overview

The systematic approach to the conservation of AnGR for food and agriculture started in the last decades of the past century. Increasing threats to global biodiversity registered by scientists and researchers – extinction of species, destruction of ecosystems and habitat, the loss of genetic diversity within the species utilized in agriculture – have contributed to the creation of a large social consensus on the need to maintain and protect biodiversity as the basis for the existence of mankind. Biodiversity was also understood as a basis for the present and future food security and sustainable agriculture.

The Food and Agricultural Organization of the United Nations (FAO) has played a crucial role in increasing public awareness of the erosion of farm AnGR. Since the early 1960s FAO provided assistance to countries to characterize their AnGR for food and agriculture and develop conservation strategies. Concerted activities on AnGR in Europe started in 1980, when the European Association for Animal Production established a working group on AnGR. At the global level, the year 1980 is also the starting point, since the first expert consultation on AnGR was held in Rome at FAO headquarters.

Public awareness resulted in commitments of the world community expressed in 1992 at the "Earth Summit" held in Rio de Janeiro and the Convention on Biological Diversity signed by 150 governments and later ratified by 188 states. The Rio Summit adopted also Agenda 21 as a plan of action to be undertaken by all stakeholders at global, national and local levels. Chapter 14 of the Agenda, which deals with the promotion of Sustainable Agriculture and Rural Development, covers issues related to the conservation and development of farm AnGR (United Nations, 1993).

In 1993, FAO launched the Global *Strategy for the Management of Farm Animal Genetic Resources* to guide national, regional and global efforts to strengthen the contribution of domesticated animals and their products to food security and rural development, and to prevent the erosion of AnGR. FAO published in 1993 the *World Watch List for Domestic Animal Diversity*, with considerable contribution from European countries. Its third edition issued in 2000 showed that in Europe there were 2 576 breeds of mammalian and avian species, 48 percent of which were at risk of extinction (FAO, 2000). Through its activities and programmes, FAO greatly contributed to the growing involvement of policy-makers in its member nations in placing the issue of AnGR on their respective policy agendas.

In 1999, the Commission on Genetic Resources for Food and Agriculture requested FAO to coordinate a country-driven report on the state of the world's AnGR for food and agriculture. On the basis of 169 country reports and a number of special studies, FAO prepared the report "The State of the World's Animal Genetic Resources for

Food and Agriculture". This Report was approved by the Inter-Governmental Technical Conference on Animal Genetic Resources held in September 2007 in Interlaken, Switzerland. The Conference also approved the *Global Plan of Action for Animal Genetic Resources* and the *Interlaken Declaration* (FAO, 2007).

Conservation policies in Europe

All countries of the European Region, greatly contributed to the global process of maintaining and protecting biodiversity producing country reports on the state of AnGR. Representatives of governments, academic community, breeders' associations and other NGOs responded to FAO's initiative, participated actively in this process by preparing the country reports that gave also the opportunity to review policies, programmes and institutional capacities in the countries.

European countries have developed national programmes for the conservation of AnGR. At the time of submission of country reports (June 2005), functional conservation programmes existed in 33 out of 39 European countries, which submitted country reports. 27 countries had active *in vivo in situ* conservation, 7 had *ex situ* and 19 countries reported on the existence of cryoconservation programmes.

The legal base for the conservation programmes is provided by national governments either under legislation related with the protection of biodiversity or under legislation regulating the management of AnGR, livestock production and animal breeding. National governments are partners in the development of national strategies for the management of AnGR and they also provide funding for implementing institutions (FAO, 2007).

In the European Union (EU) specific policy measures have been developed in the frame of the activities and programmes within the Rural Development Policy. Part of the policy stresses that agro-environmental payments should continue to play a prominent role in supporting the sustainable development of rural areas and in responding to society's increasing demand for environmental services. In this context the conservation of genetic resources in agriculture has gained specific attention. This policy also provides financial support to be given to farmers rearing animals of "*local breeds indigenous to the area and in danger of being lost to farming*".

In recent years several changes were introduced in the Common Agricultural Policy (CAP), and according to the CAP reform adopted by the Council in June 2003, the vast majority of agricultural measures will be paid in the form of single farm payments, independent of the volume of the production. The new payments are linked to environmental, food safety and animal welfare standards. These changes have significant impact to the utilization of AnGR. The EU Council Regulation No 2078/92 introduces agro-environmental measures and aims to promote environmental protection and the conservation of the countryside. This Regulation opened the possibility of subsidies co-financed by the EU for the conservation of endangered breeds. This Regulation was replaced by the Council Regulation (EC) No. 1257/99, followed by the Council Regulation (EC) No. 1698/2005, which provides the framework for the new European Agricultural Fund for Rural Development since 2007. The objective is to compensate farmers who provide environmental services for the "additional costs and income foregone" (article 39:4). In Article 39:5, it is specified that the payments can be made for the "conservation of genetic resources in agriculture".

The national Agro-Environmental Programmes have been developed under the above-mentioned Council Regulations for the period 1995–2000 (EC Regulation 2078/92) and 2001–2006 (EC Regulation 1257/99). The current national policies have been developed under the Council Regulation (EC) No 1698/2005 on support for rural development by the European Agricultural Fund for Rural Development (EARFD) and (EC) No 1974/2006.

The following information on policies is based on the responses to the questionnaire received by the countries participating in the survey (15 European member countries, 2 candidate countries, 2 potential candidate and 2 non-EU member countries).

In Austria, after 1995 when the country joined the EU, the conservation of endangered farm animal breeds was tied down to the ÖPUL Programme (Austrian Agro-Environmental Programme) referring to the EC Regulation 2078/92. Since then, three ÖPUL Programmes were realized (Fischerleitner, Baumung and Berger, 2009):

- 1995/2000 ÖPUL – 20 breeds
- 2001/2006 ÖPUL – 30 breeds
- 2007/2013 ÖPUL – 31 breeds.

In the OPUL 2007–2013, 4911 farmers join the action "conservation of rare breeds of farm animals".

France has established the National Strategy for Biodiversity with five strategic axes aiming at the enhancement of the consideration of biodiversity priorities in agricultural policy (Stratégie National pour la Biodiversité, 2009). A specific axis refers to the protection and enhancement of the diversity of genetic resources for food and agriculture with priority objectives being the sustainable utilization of genetic resources, *in situ* and *ex situ* conservation, the promotion of animal breeds of small population and the adaptation of the national regulations according to the international commitments. In 2008, in accordance with the national strategy for the protection of biodiversity, the Bureau de Ressources Génétiques (BRG) together with the French Institute for Biodiversity (Institut Français de la Biodiversité) formed the Foundation for the Research on Biodiversity (Fondation pour la Recherche sur la Biodiversité [FRB]).

The National Rural Development plan of Cyprus supports the conservation of endangered native farm animal breeds of cattle and sheep.

The German Breeding Act (2006) rules the conservation of genetic diversity as a major objective. It includes directions for the establishment of monitoring, subsequent *in situ* conservation programmes and cryoconservation measures, and thus reflects the major objectives of the "National Programme for Conservation and Sustainable Use of Animal Genetic Resource". The National Programme was developed because of Germany's commitment to the conservation of its genetic resources. It was agreed between all stakeholders involved and approved by the German Conference of Agricultural Ministers in 2003. Furthermore, surveys, inventories and studies in the area of biological diversity are carried out by the Federal Agency of Agriculture and Food. In 2007, the National Committee on Farm Animal Genetic Resources worked on the amendment of the relevant legislations dealing with the conservation and management of endangered animal breeds. The Committee is responsible for monitoring the status of indigenous breeds under control, and to initiate specific measures when needed.

In Greece and Hungary, conservation of AnGR is carried out in the frame of the countries' respective National Strategic Plans for Rural Development for 2007–2013. Responsible bodies are the Ministry of Rural Development and Food (Greece) and the Ministry of Agriculture and Rural Development (Hungary). In both National Plans, there are two specific measures, dealing with the conservation of autochthonous animal breeds at risk and the conservation of AnGR.

Conservation programmes in Ireland were implemented in the frame of the Rural Environmental Protection Scheme, whereas currently these programmes are included in the new Agro-Environmental Options Scheme. Additional payment is provided to the farmers of the Kerry Cattle Breed to support the conservation and sustainable use of the breed.

In Italy, the Rural Development Plan is managed by each region. During 2009, the Italian Government was working on a new law on biodiversity protection and use.

Slovenia has developed the National Programme for the Conservation of Biodiversity of animal production (2010–2016). The University of Ljubljana is in charge of monitoring, phenotypic and molecular characterization of indigenous breeds and related research.

The Rural Development Plan of Malta deals with the conservation of genetic resources for agriculture. Currently, the only breed supported is the Maltese cattle. In Romania, specific decisions define the eligibility criteria for conservation and utilization programmes of genetic resources.

The Spanish National Program for the Conservation, Improvement and Promotion of Livestock Breeds has been launched in 2009, by the Ministry of Environment and Rural and Marine affairs (MARM), which includes seven strategic priorities aiming at the organization of the Spanish animal genetic heritage, guaranteeing the conservation of breeds at risk of extinction and the improvement of breeds with already established position, in order to use them in the context of the new model of animal production according to EU directives and FAO's Global Strategy.

Sweden has developed the *Action Plan for Long-term Sustainable Management of Swedish AnGR 2010–2020*. The Action Plan describes the Swedish AnGR, presents how Sweden will conserve and utilize the AnGR in a sustainable manner, describes the actors involved today and suggests which actors may involved in the future and identifies the available resources and the needs (Swedish Board of Agriculture, 2009). The overall responsibility for the implementation of the Plan is of the Swedish Board of Agriculture. The Swedish Biodiversity Centre, in collaboration with the Swedish Board of Agriculture, has the role to coordinate the implementation and follow-up of the action plan. Other countries such as Denmark have developed similar Action Plans following the Global Plan for Action and other countries are on the way to develop their countries' Action Plans.

Conservation activities in the United Kingdom have a long tradition, with the involvement of individual breeders, breed societies, charities and non-governmental organizations. Native breeds at risk have benefited from significant support programmes provided by NGOs. Customized conservation programmes specifically for rare breeds have been designed and implemented by the Rare Breed Survival Trust (RBST) (founded in 1973) and a small number of other NGOs to deliver maximization of the entire breed genetic variability. Programmes such as the Heritage Gene Bank, Traditional Breeds Incentives, scrapie genotyping and breed structure analysis have all had a significant impact on native breeds at risk generally. The Poultry Club of Great Britain and the Rare Poultry Committee of the RBST have undertaken the organization of the 241 pure breeds of poultry, bred mainly for the show-ring. Farm Animal Genetic Resources policy in the United Kingdom has been strengthened by the endorsement of the National Action Plan for FAnGR by each of the four UK Agriculture Ministers. The Plan was produced by the ad-hoc National Steering Committee on FAnGR and published in November 2006. One of the key recommendations of the Plan was the creation of a National Standing Committee on FAnGR, to continue the advisory work of the ad-hoc group and to oversee the implementation of the Plan. The Committee acts as an independent non-departmental advisory public body. The Plan is intended to build on United Kingdom's strong tradition of non-governmental commitment to protecting our FAnGR. But, there are clearly areas where Government input and resources are needed, both to improve outcomes

of Government policies and to help coordinate the activities of others.

Iceland has a specific law on agriculture since 1998 that deals with the protection of biodiversity. The responsible body for the management and conservation of AnGR is the established Agricultural Genetic Resources Committee.

Serbia is implementing a system for funding *in situ* conservation of AnGR since 2003. The government supports farmers raising autochthonous animal breeds that are at risk. Montenegro has developed the National Programme for the conservation and sustainable use of AnGR for the period 2008–2013.

In Turkey, the Regulation on Protection of AnGR established in 2002 sets the procedures and principles regarding all activities related to the protection and registration of FAnGR in the country. A National Committee is established that determines the activities, reviews the past activities, specifies the breeds under threat of extinction, formulates policies and decides on the import and export of AnGR.

Norway and Switzerland have developed their national programmes for the conservation of biological diversity with reference to the UN Convention on Biological Diversity and the Global Plan for Action for Animal Genetic Resources. Since 2006, the programmes for conservation of animal, plant and forest genetic resources are merged in the established Norwegian Genetic Resources Centre organizing all programmes for genetic resources for agriculture. A specific programme (National Strategy) for farm AnGR is implemented for the period 2008–2010. In Switzerland, the official recognized breeding organizations submit programmes for FAnGR conservation to the Federal Office of Agriculture (FOAG). FOAG grants contributions for 3-year programmes to the selected programmes for funding.

Calculation of support

For the EU member countries, the procedure for the calculation of the level of support follows the guidance set out in the EC Rural Development Regulations and primarily considers additional costs and income foregone related to the commitments made by agreement-holders. For the period 2007–2013, the amount is fixed in the beginning of the programme and funds are generally allocated per breeding animal, whereas the level of support may be differentiated per country, and also in some cases within the country according to the degree of endangerment, the sex of the animals or the region. The main substantial change that is common in most of the cases is that the support is calculated using the cost estimated by breeders organizations to carry out their activities.

In Austria the subsidies are differentiated according the status of the breed; endangered and highly endangered breeds and the sex of the animals. Higher subsidies are paid for males, due to the fact that keeping male breeding animals is more demanding and also raising and increasing the use of more potential sires is desirable in conservation breeding (Fischerleitner, Baumung and Berger, 2009).

In Germany, the regions (*Länders*) are responsible for the implementation of support measures. Under certain provisions of the Act, the *Länder* must introduce their own regulations alongside those issued by the Federal Government. This results in differences between the regions, both in the level of support and on the number of endangered breeds that are supported. The level of support varies also according to the type of animal (i.e. the support per breeding animal for the production of embryos within a breeding programme is higher than the support of female breeding animal). Similar situation exists in Italy, where the funding is managed by each region.

In the United Kingdom the beneficiaries of the programmes are the holders of appropriate agro-environmental scheme agreements (England, Scotland and Northern Ireland). Specific payments are foreseen in England and Scotland for conservation grazing.

In Northern Ireland a payment of £125 per annum for Irish Moiled Cattle is available on the following conditions:

- The owner must be a participant in Agro-Environmental Scheme.
- Only female animals of at least 12 months of age at application are eligible.
- The business must provide ear tag numbers so that a manual cross-reference with the NI cattle database can be made.

In Wales support is given to native breeds directly and indirectly through other schemes such as

- Farming Connect – breeding work with native breeds.
- Supply Chain Efficiency projects e.g. native breeds – Welsh Pig project.
- Processing and Marketing Grants –support marketing schemes.

In Switzerland, support is paid per animal for accomplished actions (mainly breeding actions, i.e. increase in the number of herdbook animals per herd, increase of number of breeding males, breeding production parameters or decrease of inbreeding coefficient). The level of support per action is defined in the submitted programme. Breeding organizations submit projects with effective costs, FOAG approves and accords grants to a maximum of 80 percent of costs.

The Croatian Agricultural Agency manages *in vivo* conservation programmes for 23 breeds of farm animals. The 2749 farmers included in programmes have received in 2009 about 33 million HRK (cca 7.7 million EUR). The funds have been ensured in the budget of the Ministry of Agriculture.

The mechanisms in the different countries related to the management and conservation of FAnGR differ both on the establishment of specific bodies that deal with the

issue and on the use of the existing infrastructures. However, in all cases the responsible body for the allocation of funds is the National Government (i.e. *Ministry of Rural Development and Food, Ministry of Agriculture and Fisheries, Ministry of Agriculture, Forestry, Environment and Water Management, Ministry of Agriculture, Forestry and Food, Board of Agriculture, etc.*) and the beneficiaries are the farmers (Breeders' Associations). The Rural Development Plans that support the conservation of genetic resources in agriculture are extended to public entities, research institutions, private bodies, non-governmental organizations, producers' organizations and associations.

In Europe in general, over the last 10 years the policy has changed because of the different system settings. The policies at the EU level were highly influenced by the idea of being able to rectify mistakes of the past. Today, funding procedures depend heavily on the confirmation of the requirements by applicants. At present, the support in most cases is calculated on the basis of the estimated cost by breeders' organizations to carry out each activity. Furthermore, new tools are implemented to support the conservation of AnGR by utilizing new concepts such as the food quality and agro-environmental commitments (RDP).

Aims and activities

The number of breeds that are included in the *in situ* conservation programmes in the different countries surveyed is presented in Table 1 and Figure 1. All participated countries reported that their National Programmes (Agro-Environmental Programmes) include specific activities. The Breeders' Associations submit project proposals and request to be funded for these specific actions. The main activity that is funded is the registration in herdbooks. Other activities that are eligible in the national programmes is parentage testing (i.e. in Ireland it is carried out by DNA sampling as part of herdbook registration, in Switzerland it is partly mandatory for breeding males and in Sweden it is done for few breeds).

Several activities are initiated by breed societies and breeders' organizations regarding breed promotion, including shows, relevant websites development, publications. In Germany, 74 promotion schemes of the *Länder* are established under the Reg. (EC) No. 1698/2005 for 45 different breeds of horses, bovine, pigs, sheep and goats. However, specific studies to estimate the contribution of the private sector in *in-situ* conservation programmes do not exist.

Ireland reported that projects for genetic characterization are funded by the National Advisory Committee, carried out by herdbooks, studbooks and flockbooks. Semen from rare cattle breeds is available via national commercial AI network, whereas semen from the Irish Draught is also available. Performance recording is carried out by the Irish Cattle Breeding Federation for cattle, sheep and horses and also by Teagasc for Galway sheep (State Agricultural Advisory Service).

In Spain new instruments are included in the conservation programmes to support concepts as food quality and

Table 1. Current situation of the *in situ* conservation projects.

Counties	*In situ* conservation						
	Cattle	Buffaloes	Sheep	Goats	Horses	Ass	Pigs
Albania	1	1	4	4			
Austria	9		8	7	5		2
Croatia	2		2		2		2
Cyprus	1		1				
France	18		27	5	14	7	6
Germany	19		20	1	14		8
Greece	2	1	10	1	4		1
Hungary	1		5	1	8		3
Iceland				1			
Ireland	3		1		3		
Italy	14		4	16	9	6	6
Latvia	2		1	1	1		1
Malta	1						
Montenegro	1		3				
Norway	6		6	1			
Romania	1	1	13	2	4		2
Serbia	2	1	8	1	2		3
Slovenia	1		5	3	5		3
Spain	31		33	17	13	6	9
Sweden	5		8	4			1
Switzerland	5		3	7	1		
Turkey	6		13	5			
United Kingdom	30		42	2	14		9

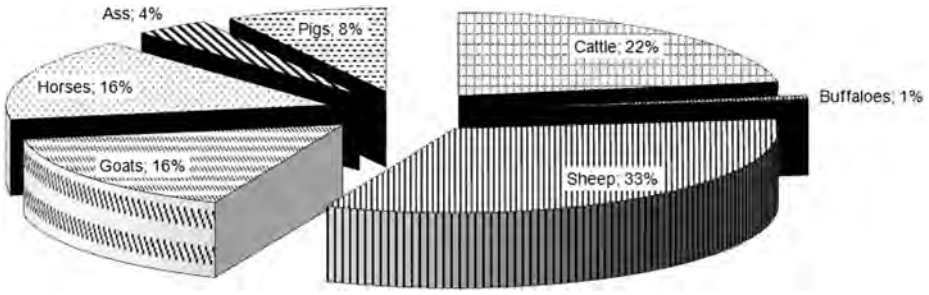

Figure 1. *In situ* conservation programmes in the 21 countries participating in the survey.

agro-environmental commitments, the production of quality products through specific legislation particular from autochthonous breeds. The Royal Decree 1615/2007 established aids for support certification schemes in animal origin products production.

The Icelandic Commission on Genetic Resources in Agriculture in May 2009 has completed a strategic plan including an analysis of the current status and proposals of necessary actions regarding the conservation of all genetic resources in Iceland for the period 2009–2013.

Cryoconservation

In the years following the preparation of the *State of the World Report*, significant progress has been made in the development of cryoconservation activities in Europe. As it is shown in Table 2, in almost all countries, even if a national structure (i.e. *National Cryobank*) is not operating, there are discussions and considerations on establishing one, either by coordinating the actions of the existing gene banks or by creating a new Institution. The necessity of coordinating the ongoing cryoconservation activities is recognized by all NCs that participated in the survey. In addition to the organization at national - or regional - level actions, in all countries relevant initiatives are developed by Research Institutes, University Laboratories, Breeders' Associations or other NGOs. The situation of cryoconservation in Europe is presented as follows.

In Belgium a 5-year cryoconservation programme launched in April 2010, coordinated by the University of Louvain aiming to set up the Cryobank of Wallonie. Sheep is the first specimen to be collected for cryoconservation followed by cattle. It is reported that the preliminary studies conducted for 4 years resulted in benefits that go largely beyond the Cryobank itself. An original investigation method was developed that was applied for the in-depth study of four sheep breeds, generating useful results, not only concerning the animals to be collected, but also in terms of inventory, breeding advice, etc. (Annual Report (Belgium), 2010).

Czech Republic reported on the going activities on the collection and cryostorage of semen, somatic cells, ovaries and blood samples. An ex-situ conservation of nucleus of the original Czech Red-pied cattle was established by buying 20 autochthonous cows, production of embryos for cryostorage in genebank (70) and transfer of other 26 embryos to recipients (Annual Report (Czech), 2010).

In France, the National Cryobank was created in 1999, co-funded by 11 different organizations that signed the convention. The main signatory is the French Ministry of Agriculture, which is the major financial source. The other partners represent administration, research and breeders' organizations (Danchin-Burge and Hiemstra, 2003).

In Germany, the Breeding Act rules that Ministry of Food, Agriculture and Consumer Protection (BMELV), with agreement of the Federal Government, can develop basic guidelines for a National Cryobank that specify the conditions under which material is regarded as part of the National Cryobank, as well as the conditions that apply for using material thereof. The organization and creation of a structural model for a "National Cryobank" were assigned to Friedrich-Loeffler Institute (FLI) in Mariensee, which will comprise the building of central storage facilities and management of the reserve. Discussions between all relevant parties – BMELV, *Länder* Ministries, BLE, FLI and the National Committee on AnGR – towards establishing a national gene bank continue (Annual Report (Germany), 2010).

In Hungary, the Ministry of Agriculture and Rural Development and the Ministry of Environment and Water established in 2008 a specific working group (Gene Bank Special Body) for the genetic resources for food and agriculture. This working group works on surveying the needs, and will make proposals for the government in the field of protection of the genetic resources (including legal and financial measures).

In Italy, special attention is given to the establishment of a national system of cryoconservation of genetic resources. The system aims at creating a network among cryobanks that are currently active in the country, developing a common and shared information system to have a more efficient coordination of the different initiatives (Annual Report (Italy), 2010).

In Ireland, projects for semen and embryo collection and storage are funded by the National Advisory Committee. There are also some private collections initiated by

Table 2. Current situation of the cryoconservation activities in Europe[1]

Counties	Activities	Counties	Activities
Austria	Austrian Gene Bank for FAnGR	Malta	Exist for Maltese Ox
Belgium	Implement project for the establishment of the National Cryobank – April 2010	Montenegro	Existing collections
Croatia	Under development – project to establish national gene bank	Netherlands	Gene Bank Foundation established in 1993. Since 2002 CGN manages gene bank collections
Cyprus	Under development – project to establish national gene bank	Norway	Existing gene banks for all cattle, sheep, goat and dog breeds worth of conservation. Gene bank for poultry
Czech Republic	Operating	Poland	Under development – project to establish national gene bank
Denmark	Operating	Portugal	Operating
Finland	Operating	Romania	Some collections
France	National Cryobank. Other collections: private sector, research institutes	Serbia	Not operating – semen from Busha cattle is stored in reproduction centre
Germany	Exist several gene banks – discussions between all relevant parties towards establishing a national gene bank	Slovenia	Existing for bulls and three breeds of sheep
Greece	In the frame of research initiatives – under consideration for the establishment of national gene bank	Spain	Operating
Hungary	Operating	Sweden	Operating
Iceland	Operating semen collections	Switzerland	Exist cryobanks in institutions for cattle, goats, sheep and horses – under development of a national gene bank
Ireland	Projects for semen/embryo collection and storage. Some private collections. Working group formed to provide guidance for the creation of an *ex-situ* national gene bank	Turkey	Operating
Italy	Under development of a common information system to coordinate all existing gene banks	United Kingdom	Operating Heritage Gene Bank, RBST bank, Bovine Semen Bank
Latvia	Some collections in the Latvian University of Agriculture		

[1]The table includes the countries participated in the survey or submitted the relevant information in their Annual Report (2009–2010).

breeders. In 2009, a working group was formed to provide guidance regarding the creation of an *ex-situ* national AnGR Genebank. The holders of existing collections are to be approached seeking expressions of interest in providing material to the national gene bank.

Within the first efforts to develop a national gene bank is the establishment of the Dutch Gene Bank Foundation (SGL) in 1993. By the end of the 1990s, SGL transferred the management of the gene bank to the DLO Foundation (Agricultural Research Service Foundation [*Dienst Landbouwkundig Onderzoek*]). Since 2002, the Centre for Genetic Resources (CGN) has been managing gene bank collections (Danchin-Burge and Hiemstra, 2003).

In Poland during 2009, the plans for the establishment of the National *Ex-situ* Gene Bank for Animal Genetic Resources in the National Research Institute of Animal Production in Balice were further developed. A routine collection of semen of Polish Red, Polish Red and White, Polish Black and White and Whitebacked bulls identified as sires in the respective conservation programmes (at least 200 portions per sire) has been initiated (Annual Report (Poland), 2010).

In the United Kingdom, the RBST is currently raising funds and collecting semen for national rare breeds *ex-situ* conservation archives. Although the RBST had for many years collected, stored and distributed rare breed cattle semen, the need to expand the archive to include other farm species became urgent as a result of the 2001 Foot and Mouth Disease epidemic. Programmes to conserve AnGR have been undertaken by commercial companies and marketing organizations (e.g. the Milk Marketing Board Museum Bank of bovine semen established in 1969), as well as NGOs and private individuals (multi-breed collections).

The Swiss Parliament agreed to introduce a new paragraph in the ordinance for animal breeding, which allows co-financing of long-term conservation of cryomaterial together with organizations for artificial insemination. The activities for 2010 focused on *ex-situ* conservation programmes for goats, as well as on long-term strategies for the management of the cryobank for cattle, horses, goats and sheep. Contracts for long-term conservation of cryomaterial and for the utilization of the cryoweb will be concluded (Annual Report (Switzerland), 2010).

Research initiatives

Several research projects are ongoing in Europe in relation to the conservation and management of Farm Animal Genetic Resources. In the first Community programme

for the period 1994–99 (Council Regulation 1467/94) on the conservation, characterization, collection and utilization of genetic resources in agriculture, four projects for AnGR were funded, covering cattle, inventory of farm AnGR, pigs and rabbits.

The EU launched a new Community programme in the frame of the Biodiversity Action Plan for Agriculture (Council Regulation 870/2004) on the conservation, characterization, collection and utilization of genetic resources in agriculture. This programme aimed to promote genetic diversity and the exchange of information including close coordination between Member States and between the Member States and the European Commission for the conservation and sustainable use of genetic resources in agriculture. Furthermore, it aimed to facilitate coordination in the field of international undertakings on genetic resources.

In the two calls of (EC) Regulation 870/2004, five projects related to the conservation of AnGR were selected for funding: 012 – *Towards self-sustainable European Regional Cattle breeds*; 020 – *An integrated network of decentralized country biodiversity and genebank databases*; 040 – *HeritageSheep*; 066 – *European Livestock Breeds Ark and Rescue Net*; 067 – *Global View of Livestock biodiversity and conservation.* In total 19 European countries participated in one or more GENRES actions, started in 2007 and having a maximum duration of 4 years. In practice, more countries were involved in these activities, as workshops with wider participation were organized in the frame of the above projects. Furthermore, close cooperation was achieved between research institutions, the private sector and non-governmental organizations, and in some of the projects, from direct interaction with farmers, who ultimately take care of, use and conserve the genetic resources. The results and outcomes of these projects funded had also significant value to inform decision-making on agro-environmental measures within the European Commission (http://ec.europa.eu/agriculture/genetic-resources/actions/index_en.htm).

In all countries several ongoing research projects were reported dealing with the genetic characterization, conservation and management of AnGR, funded either under the European research framework or included in national frameworks. These projects deal with molecular genetics and biotechnology for genetic characterization, sustainable use of local AnGR, cryopreservation, innovations and valorization of products.

The European Regional Focal Point for the management of AnGR (ERFP), in the frame of its Annual Calls for Action has funded since its establishment, in total 24 projects with considerable results. The areas included in these Calls, cover issues related to breed development and conservation, *in situ* and *ex situ* monitoring AnGR, development of the Regional Focal Point and support to NCs in policy development and direct assistance to particular country or group of countries in supporting activities of the National Focal Point. Furthermore, specific topics selected by the NCs in the ERFP Annual Workshops were included in the last Calls (Georgoudis and Ligda, 2010). The ERFP, according to the new Terms of References, will no longer launch a Call for Action but financially support projects as *Ad hoc* Actions, where appropriate (ERFP, 2010).

Expected benefits

Additional expenditure for keeping endangered breeds because of reduced economic competitiveness is complex to estimate objectively. Furthermore, the expected benefits are difficult to assess. One of the main justifications for social, cultural, economical and environmental protection of biodiversity is that a new vision of the economy is needed that takes into account the utilization of the benefits that nature can give to humanity, whereas at the same time measures are taken to assure that their potential will not be exhausted. In the frame of the survey, an attempt was made to assess these benefits, in economical, social, cultural and environmental levels. Several responses were received, which are summarized as follows.

Economical

For most of the countries the niche markers for distinctive livestock products are recognized as potentially important to the economic viability of many local breeds. EU legislation provides a number of schemes under which distinctive products can be registered (i.e. Protected Destination of Origin (PDO) and Protected Geographical Indication (PGI)).These schemes do not explicitly imply that a product should originate from a specific breed, but even if not, the local breeds are promoted under these schemes, which require traditional production systems in specified locations and in this way the continued utilization of the local breeds is supported (Zjalic *et al.*, 2010).

A labelled local typical product is an informative example where the use of biodiversity, linked to the diversified resources of a “bioterritory” ‘or “bioregion” is irreplaceable and essential. Data on 332 animal products of protected origin (PDO) form 17 Member States of the EU that apply both the system of registration and protection of geographic origin of animal products (PDO and PGI) and the system of conservation of farm AnGR show that one-third of PDO/PGI cow cheeses, almost all sheep and goat cheeses and all cheeses made of mixture of cow, sheep and goat milk, or sheep and goat milk come from local breeds. The EU system of registration and protection of geographic indication of origin of quality traditional animal products contributes also to the sustainable utilization of 14 percent of cattle breeds, 10 percent of sheep breeds and 11 percent of goat breeds covered by *in-situ* conservation programmes (Zjalic *et al.*, 2010).

Special reference is given by Italy on the key role of labelled local products for health sustainability of both

human and "bioterritory" or "bioregion" and their positive impact also on the "economical sustainability". The health aspect of a food product justified by the identification of indicators of "nutritional and extranutritional quality", specific for each product in a given land context, is currently rising and must be assessed and investigated in all its aspects. The autochthonous germplasm, especially if ancient, in its diversity, could play a unique role to solve problems related to human nutrition, as a source of an "immeasurable wealth" of variable active components, particularly in function of the soil and climate of a given "bioterritory". The integration between the various branches of the "omic" science is likely to explain the "nutritional", "extranutritional" and "healthy" quality of local product through the identification and characterization of molecular biomarkers of genetic "uniqueness" (at the level of a single individual) and "specificity" (at the product level), leading also to their proper rescue (Matassino, 2009, personal communication).

It is expected that the volume of domestic products on the field of agriculture will increase. Furthermore, local breeds are able to exploit secondary productions of agriculture and pastures with low value and contribute to sustain the economical activities in rural areas. The net economic benefit from the conservation programmes has not been measured yet. In this context further research is needed to find objective indicators to measure these benefits.

Social and cultural

Biodiversity of farm animals is a part of global biodiversity and represents an integral part of human life and human activities. It is also considered to be an important factor of food security and investment in the well-being of future generations. In social context, the main benefit comes from the contribution of local breeds to maintain activities in rural areas. Keeping livestock farming provide employment and income sources in areas where other economic sectors are not well represented. A number of breeds are only kept for subsistence farming or to maintain our cultural heritage.

Several countries responded that native rare breeds are considered as a tourist attraction in a number of sites, generating a certain income as reported by Austria, Ireland, Sweden and Switzerland. Farm Parks in the United Kingdom carry out important work in the field of conservation and many provide educational resources. Some of them are approved by RBST and are involved in the conservation, breeding and promotion of rare or endangered breeds of farm animals. There are currently 16 Approved Farm Parks around the United Kingdom operated by local authorities, charities and by individuals who have diversified their farming activities (www.rbst.org.uk).

Environmental

Conservation programmes have significant contribution to the International Convention on Biological Diversity obligations and this should be considered as a core component of Biodiversity Plans in all countries.

Specifically, ancient and rare local breeds are used for landscape management and in environmental projects. Grazing animals, particularly well-adapted breeds of sheep, cattle and horses play an important role in nature management. This role offers an excellent opportunity for the conservation of these breeds. As already mentioned above, the changes in the system of funding of AnGR conservation in the recent years include the agro-environmental scheme agreements in the United Kingdom. Several other examples have been reported in the survey; in Austria, the risk of avalanches in high Alps is reduced by keeping grazing steep slopes above the tree limit; in Ireland, native cattle and sheep breeds are being looked at for their role in grazing of specific habitats of environmental interest; in France, local breeds are used for landscape management (mountains, wetlands) for the protection of Mediterranean forests against fire.

Conclusions

In the EU, costs of conservation of endangered breeds represent a marginal fragment of the total financial support to the livestock sector. The financial support for the breeders is secure until 2013 but conservation is an ongoing process and it is necessary to continue such conservation measures and after 2013 and to support the breeders of endangered breeds financially. It could be expected that conservation programmes would be supported by national and Community authorities in various forms including the financial contributions to non-production functions of local breeds and specific policy measures contributing to the sustainable use of underutilized farm AnGR.

The survival of endangered breeds depends on the increase in their productivity and in their competitiveness especially in the niche markets for high-quality products. This could be supported by the revision of the system of protected (PDO and PGI) products of animal origin and the introduction of request for specific declaration of breeds from which animal products originate.

In a number of Member States of the EU as well as in rural development policy in the EU, the non-production role of local breeds has already been recognized, i.e. the use of local breeds for landscape management and the protection of the environment. These cultural functions and values require public attention and support. Furthermore, the potential of local breeds for diversification of sources of income of rural families such as gastro and ethno-tourism should be promoted and valorized. The concept of biodiversity as the public good has already been accepted by European public and by policy-makers. The additional scope of protection of farm animal biodiversity, as an investment in the future food security, needs to be reflected in the future policies.

Several issues are associated with the calculation of the costs of the conservation activities. One aspect is the level of support per head for the *in situ* programmes and the costs related to the collection, conservation of genetic material, which varies a lot according to the techniques used, the species involved, the objectives and the size of the gene bank, the existing resources, etc. Furthermore, under conservation programmes different activities are carried out depending on the existing National Action Plan for the management and conservation of AnGR and the involvement of the Breeders' Associations. Such activities include the registration in herdbooks, performance recording, parentage testing, genetic characterization, demographic characterization, *ex-situ* conservation, artificial insemination, genetic evaluation and improvement, breed promotion and dissemination activities. A part of these activities are covered by the national programmes, whereas others by the farmers themselves or by different research initiatives. A clear partition of the part of the funding to the different contributors was not possible to be achieved in the frame of the present work. A number of research papers are available concerning the costs and benefits of conservation, using different approaches and valuation methodologies (Cicia, D'Ercole and Mario, 2003; Scarpa *et al.*, 2003; Signorello and Pappalardo, 2003). This review paper presents a general view of the evolution of the different conservation activities and the way the countries (of the EU and of the whole region of Europe) perceive the development of these actions in the future by estimating their benefits, in economical, social, cultural and environmental aspects. Among the main outcomes of the survey is the importance to find new opportunities for funding the work on the conservation of AnGR. In this context the conservation work can be incorporated with the issues of food security and sustainability, the protection of the environment and climatic change, concepts on which the interest of society is continuously increasing.

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Early animal genetic resources conservation in Scandinavia – first decades of identification and conservation of animal genetic resources in Scandinavia

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Summary
Conservation of animal genetic resources (AGR) in Scandinavia was started in the 1970s and organized in the 1980s. The work is coordinated by a working party financed by the Nordic Council of Ministers. Each country conserves its own AGR, but many tasks can be done jointly. Of these tasks, the development and maintenance of a Nordic data bank for AGR is an important part. Each country has mapped out its situation and prepared plans for conserving endangered native breeds and genetic variation in some major breeds for unpredictable future needs. Live animals from several breeds have been conserved in agricultural schools, prison farms and private herds, but these have been supplemented by stores of frozen semen and embryos. Developments in conservation methods are followed up and problems of conservation pointed out. Many of these are caused by the fact that animals grow, age, die and have to be mated regularly with unrelated animals, and that records have to be made of identities, mates, dates and traits. Many precautionary measures are necessary. Many-sided frozen semen and embryo stores are important besides live animal herds or flocks. There are problems in getting each female inseminated with an appropriate male, and in getting people working on different motives to collaborate.

Keywords: *conservation, data bank, frozen, genetic resources, live*

Résumé
La conservation des ressources zoogénétiques en Scandinavie a été lancée dans les années 1970 et organisée dans les années 1980. Un groupe de travail financé par le Conseil nordique des ministres est chargé de la coordination. Chaque pays conserve ses propres ressources zoogénétiques, mais plusieurs fonctions sont entreprises de façon conjointe. Une partie importante de ces tâches est représentée par l'élaboration et par le maintien d'une banque de données nordique pour les ressources zoogénétiques. Chaque pays a cartographié sa situation et préparé des plans pour la conservation des races locales en danger et de la variation génétique de certaines races principales en cas de besoins imprévisibles à l'avenir. Les animaux vivants de plusieurs races sont conservés dans les écoles d'agriculture, dans les fermes des prisons et dans les troupeaux privés. A complément des troupeaux, on détient également des réserves de sperme et d'embryons congelés. Les développements qui interviennent dans les méthodes de conservation sont suivis et l'on attire l'attention sur les problèmes associés à la conservation. La raison de plusieurs de ces problèmes est que les animaux grandissent, vieillissent, meurent et il faut les accoupler régulièrement avec des animaux sans lien de parenté, et qu'il faut enregistrer les identités, les animaux accouplés, les dates et les caractères. Il est nécessaire de mettre en place de nombreuses mesures de précaution. En plus des troupeaux d'animaux vivants, il est important de disposer de réserves de sperme et d'embryons congelés à plusieurs facettes. Il existe des problèmes dans le choix du mâle approprié pour l'insémination de chaque femelle et à faire collaborer des intervenants qui travaillent à partir de motivations différentes.

Mots-clés: *animaux vivants, banque de données, congelé, conservation, ressources génétiques*

Resumen
La conservación de los recursos zoogenéticos (AGR por sus siglas en inglés) en Escandinavia comenzó en los años setenta y se organizó en los años ochenta. Es tema está siendo coordinado por un grupo de trabajo financiado por el Consejo Nórdico de Ministros. Cada país conserva sus propios AGR, pero muchas tareas pueden ser abordadas de forma conjunta. Una de estas tareas, relacionada con el desarrollo y el mantenimiento de un Banco Nórdico de Datos para los AGR, es una parte importante. Cada país ha planificado su situación y preparado planes de conservación para razas locales amenazadas y relacionados con las diferencias genéticas en algunas razas mayores, de cara a impredecibles futuras necesidades. Animales vivos de muchas razas se han conservado en escuelas de agricultura, granjas y rebaños privados, pero éstos han sido complementados por reservas de semen congelado y embriones. Se ha llevado a cabo un seguimiento del desarrollo de los métodos de conservación y se han indicado los problemas relacionados con la conservación. Muchos de éstos son causados por el hecho de que los animales crecen, envejecen, mueren y tienen que

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ser cruzados regularmente con animales sin parentesco en común, y que los registros tienen que hacerse de las identidades, cruces, fechas y características. Es necesario poner en marcha medidas preventivas. Son importantes las reservas multilaterales de semen congelado y embriones, además de los animales y los rebaños de éstos. Existen problemas a la hora de inseminar a cada hembra con el semental apropiado, y para conseguir que las personas que colaboran estén motivadas.

Palabras clave: *banco de datos, congelado, conservación, recursos genéticos, vivir*

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Introduction

Scandinavia comprises five countries: Denmark, Finland, Iceland, Norway and Sweden. They have many similarities in natural conditions, history and culture. Animal production has long been an important sector of agriculture, and production techniques have been developed also in collaboration between countries. According to Gjelstad (1993) the number of breeds at the end of 1980s were about 22 cattle, 20 horse and sheep, 8 pig and 7 goat. Some native and international breeds occurred in more than one country. Each country had its own native layer breed of hens and several international ones. An analysis made by Kantanen (1999) with 29 genetic markers on the genetic distances between 15 indigenous, 2 old imported and 3 commercial Nordic cattle breeds revealed that the Icelandic cattle were related to the three Finnish native cattle breeds and that they have had the last common ancestors with the east-Finnish cattle ca. 400 generations or ca. 2 000 years ago. The study by Tapio (2006), using mitochondrial control region and autosomal blood protein variation in 76 sheep breeds in northern Europe showed, that the main maternal origin of northern sheep is in the south, and that there were four distinct maternal lines in Europe. The analysis separated long- and short-tailed sheep.

There are many organizations both on the scientific and practical level, for cooperation, e.g. the Scandinavian Association of Agricultural Scientists (SAAS) established in 1918. Nordic experience of conservation of animal genetic resources (AGR) may be of interest to similar groups of countries, which could profit from cooperation. Motives for conservation, principles in choosing breeds for conservation, various problems and other details can be found from earlier reports (Maijala, Ehrenberg and Kolstad, 1981; Maijala, 1984, 1985 , 1990; Maijala *et al.*, 1990a, 1990b, Maijala and Kolstad, 1992).

Development of conservation ideas

Worries about possible losses of genetic variation in farm animals were expressed in a Nordic cattle breeders' meeting already in 1954, when possible consequences of using frozen semen in cattle were discussed (Hansson, 1954). In the 1960s, similar worries were raised because of the spread of "hybrid breeding" in layer hens and by the rapid decreases in the population sizes of some native Nordic populations of cattle, horses and sheep (Maijala, 1970). Since then, more and more thought has been devoted to the risks of gene and breed losses in various farm animals in the region. Table 1 shows that isolated conservation activities were started in all the Nordic countries and in several species in the 1960–1970s.

The UN Environment Conference in Stockholm in 1972 emphasized the importance of conserving genetic material. Its recommendations included actions, which the different states should undertake for conserving and managing valuable genetic resources: to make inventories of genetic collections, collect and document genetic material of various organisms (including farm animals) in order to establish national and regional gene banks. Following these recommendations, the Nordic Contact Organ for Environment Problems (NCOEP) suggested, in 1973, an arrangement of a joint Nordic conference for discussing problems connected with establishment of Nordic gene banks and for preparing suggestions for concrete actions.

The world conference on AGR conservation and management, arranged by FAO and UNEP in 1980, had also Nordic participants. The author presented there a Scandinavian report on

Table 1. Early Nordic activities serving conservation of AGRs.

Year	Country	Species	Action
1965	Iceland	Goat	Law for conserving Icelandic goat
1967	Sweden	Cattle	Semenbank for ten breeds (584 bulls, 609 000 doses)
1969	Iceland	Cattle	Semen bank (30 doses/bull) started
1969	Sweden + Nordic	Hen	Control line based on seven-layer hybrids
1971	Denmark	Cattle	Semen bank (500 doses/bull) for three breeds
1971	Norway	Hen	Live gene banks for layer hens
1974	Iceland	Hen	Saving action for native hen started
1975	Finland	Cattle	Contract with five school farms on Finncattle
1976	Norway	Goat	Semen bank (50 doses/male) started
1976	Iceland	Sheep	Law for conserving leather sheep
1977	Norway	Cattle	Semen bank for three native breeds
1977	Norway	Pig	Semen bank (1 ejac./boar)
1978	Norway	Cattle	Control population of NRF cattle breeds
1979	Finland	Cattle	Breed comparison trial started
1979	Sweden	Cattle	Conference for saving Mountain cattle

AGR (Maijala, Ehrenberg and Kolstad, 1981). The conference gave recommendations to FAO and to its member governments. The author represented Scandinavia in the European AGR working party for 16 years, of which 13 years as chairman. This group collected information on the situation of endangered breeds three times (1982, 1985 and 1988) also in Scandinavia and outlined important principles concerning motives, methods and uses of gene conservation (Maijala *et al.*, 1984; Maijala, 1987; Simon, 1989).

The Nordic Council of Ministers (NCM) as an assumer of responsibility

In the years 1973–1976, the NCM made preparations for the symposium suggested by NCOEP, by mapping out the situation and by studying the possibilities to coordination. The symposium was held in March 1978 in Helsinki and concerned agricultural, horticultural and forest plants, wild plants and animals, farm animals and fish (SOG, 1978). The reports on farm animals revealed that conservation activities had already been made in all Nordic countries and in several species.

The working party on farm animals discussed the need for conserving genetic variation, the threat situation in different countries and species, activities performed, conservation methods, possibilities for utilizing conserved genes, possible actions, bureaus responsible for conserving AGR, and need and organization of collaboration between countries. It proposed that the ministries of agriculture should have the direct responsibility for the national farm animal breeds that will be conserved. It also suggested that the collaboration between countries should take place by means of an expert group in NCM and the board of the animal section in SAAS. The expert group could assume responsibility for that information on semen banks and threatened animal breeds is collected into a register, which can be utilized by researchers, public authorities, etc. No reason was seen in creating a Nordic gene bank physically as in plants.

At the end of 1979, the NCM decided to finance the activity of a Working Party on Animal Genetic Resources (WPAGR). The grant for the purpose has gradually increased from NOK 40 000 to DKK 500 000. Decisive increases took place in 1984 and 1991, for hiring first a half-time secretary and then a full-time one. Getting a secretary meant that the activities could be really started. There are signs for that understanding of conservation has increased among the public authorities and general public.

Organization of WPAGR and division of responsibilities

WPAGR was established in a board meeting of the animal section of SAAS in the winter 1980, for clarifying the possibilities to coordinate the conservation actions in Scandinavia (Maijala *et al.*, 1992). It met about three times a year. Besides the salary of the secretary, the cost of travel for him and members of the meetings of WPAGR and for data processing have been the most important cost items. Costs for symposia, extra travel, etc., which are difficult to predict, were covered by grants applied for specifically.

The WPAGR considered that, in principle, each country should take care of the conservation of its own gene resources, since the profit of it can be harvested only in the future and mainly on the national level. Hence, the activities should be divided into two levels:

National level

Each country should organize its own gene bank according to its own circumstances and priorities, and utilize its own existing resources for gene conservation, including semen and embryo stores, and animal institutes and museum farms for maintaining small populations of live animals. It should have an advisory gene bank council with representatives of as wide a society level as possible, e.g. for research in the animal field, animal management, breeding and Artificial Insemination (AI) organizations and cultural–historical as well as nature protection interests.

The council should:

- make proposals for and contribute to legislation in the area;
- create, maintain and supplement gene banks;
- contribute to the utilization of conserved genetic material;
- follow the development in the animal breeds outside the gene banks through contact with various breeding organizations;
- follow developments in conservation methods;
- work for financing the activities;
- work with information about them;
- develop contacts with corresponding international activities;
- register and mediate national base information for furthering it to the Nordic information centre.

Nordic level

A coordinating body, composed of representatives of national gene bank councils, should be created under the NMC. WPAGR should:

- organize and coordinate activities on the Nordic level;
- map out endangered populations;
- initiate formation of and contribute to realization of gene banks;
- collect and mediate information about the activities in the Nordic countries;
- create an information and data processing centre on Nordic level;

- take care of contacts with the EAAP/FAO Global AGR Data Bank:
- maintain contacts with and follow the progress of research on conservation methods, animal breeding, gene technology and culture protection, and work for application of the newest methods in storing genes;
- function as a leading group for projects in the subject area, prioritize, initiate and follow-up them;
- work for active information both on the scientific and popular levels;
- actively search for collection with similar activities on both plant and animal sides, nationally and internationally;
- stimulate and maintain contacts with corresponding international activities.

The coordinating secretary should be placed at some animal breeding institute in Scandinavia, making available the basic resources on data processing, a research environment and knowledge about the latest development in the area. WPAGR got a half-time secretary on 1 July 1984, and, on 1 March 1991, a full-time one, placed at the Institute of Animal Science, Agricultural Research University of Norway.

Mapping out the national situations

WPAGR, in which each Nordic country is represented, sent in March 1981 to the agricultural ministries of all Nordic countries a recommendation to setting up national committees for studying the situation and the present organization, with the following tasks:

- map out the present situation of the animal breeding of the country and the number of animals in the remaining native breeds, their distribution in the country and utilization;
- make clear the available methods for conservation of the gene resources of different farm animal species, and the knowledge and techniques that are available in farm animals;
- review the possibilities of conserving the genetic variation, which is considered necessary from the economic-biological, scientific or cultural-historical viewpoints;
- make proposals for hastening the conservation actions for certain animal materials (rare or endangered breeds);
- plan the gene bank for farm animals and give recommendations for the activity with estimates of financial needs.

Each country appointed a committee or a working party, as shown in Table 2. The Swedish one had been set up already in 1978 and gave valuable lines of thought for those of other countries. Cattle, goat, horse and sheep were considered in five countries, duck, fox, goose and mink in four, polecat, rabbit, raccoon dog and turkey in three and bee and reindeer in two.

Breed situation of ruminant species

Table 3 gives the situation in ruminants, which have special importance in utilizing feeds not edible by man. Each country has its own native breeds, several of which are endangered:

Cattle: Gray Jutland and Red Pied in Denmark, Eastland Red Poll, Telemark, Trönder.

Döle, Westl. Red Poll, Westland Gray Möre and Westland Fjord in Norway, west Finnish and north Finnish in Finland.

Sheep: Landrace in Denmark, landrace in Iceland, wild sheep in Norway, gute in Sweden, finnsheep (grey, brown and blue types) in Finland.

Goat: Landrace in Denmark, Iceland and Norway.

Reindeer: Wild in Norway.

These have a long background of having lived in the northern conditions and thus have special genes for adaptability to these conditions. They were developed as separate breeds since the turn of 1900s, when the theories of breed constancy and local adaptations were still prevailing. Hence, much emphasis was directed to simple visible traits such as colours and horns. Separate herd books were established for different types, and individuals not conforming to the type requirements were excluded. This may have meant losses of valuable genes for physiological and production traits. It is not known, to what extent this has happened and how big are the genetic differences between the breeds.

Also the histories are generally poorly known. However, in some cases it is known that either the background is similar or there has been exchange of breeding material. In cattle this applies, for example, to the Eastland Red Poll of Norway, the Red Poll of Sweden and the west-Finnish cattle (Blomqvist, 1989). Similarly, the Swedish Mountain cattle and the north-Finnish cattle have obtained genes from each other. Acceptance of the exchanges by people has been facilitated by the similar colours. It would be important to know, to what extent these similarities reflect similarities in origin and in genetic constitution. Hence, estimation of genetic distances between the Nordic breeds with the aid of DNA and other genetic

Table 2. National committee reports on AGR in Nordic countries.

Country	Time of setting		Time of report		No. memb	Reference
Sweden	Oct.	1978	Sept.	1980	8	Kolstad (1983), Betänkande (1980)
Denmark	Jan.	1982	Dec.	1982	7	SHB (1982), Kolstad (1983), Utredning (1984)
Finland	March	1982	Dec.	1983	9	Komiteanmietintö (1983), Kolstad (1983)
Norway	Nov.	1982	March	1984	5	Komiteanmietintö (1983), Kolstad (1983)
Iceland	March	1983	Febr.	1984	2	Adalsteinsson (1983)

Table 3. Conservation needs of Nordic ruminant breeds.

Species	Country	Number of breeds needed for conservation			
		Whole breed	National type	Within breed	None
Cattle	Denmark	2	2		11
	Finland	3	–	1	6
	Iceland		–	1	–
	Norway	7	–	1	4
	Sweden	2	1	1	6
	Total	14	3	3	27
Sheep	Denmark	1	4		1
	Finland	3	1	1	5
	Iceland	2	–	–	1
	Norway	1	–		12
	Sweden	2	–	–	19
	Total	9	4	1	37
Goat	Denmark	1	–	1	1
	Finland	1	–	–	–
	Iceland	1	–	–	–
	Norway	–	–	1	1
	Total	3	0	1	2
Reindeer	Finland	–	1	1	1
	Norway	1	–	1	–
	Sweden	–	–	1	–
	Total	1	0	3	0

polymorphisms would be important for planning the conservation and future breeding of the breeds. Since this information has not been available, the national committees have considered it important to save most of the native breeds. This has been justified also for cultural–historical reasons. Fusing similar breeds from several countries may weaken these motives of each group of owners, and may not essentially improve the economic competing ability.

The Icelandic cattle, sheep and goats are of special interest, since they have been isolated from the original Norwegian ancestors for more than 1 000 years. Thus, they can be considered live gene banks as such, especially since no discrimination on the basis of colours and types has taken place (Adalsteinsson, 1981).

For some breeds (e.g. Danish Blackpied and Red cattle breeds) the question is of preserving genes from the old Danish animals, since the breeds have used largely genetic material from similar American breeds (Holstein, Brown Swiss).

For the part of some major breeds, saving old and present genetic material for unpredictable future needs has been considered important. The Finnish population of Ayrshire is the biggest in the world, and hence Finland has assumed the responsibility for saving its genetic variation. In sheep, there are some special traits or genes, which have been considered to deserve protection, e.g. the leader sheep and the single gene for fertility in the Icelandic sheep, and some colour genes in the Swedish and Finnish landrace sheep. All the countries have landrace sheep belonging to the northern short-tailed group, most types of which are very prolific. They would deserve a special study of genetic relationships and other traits. In goats, there has been exchange of breeding material between the landraces of Norway and Sweden, to some extent also of Finland, and so one could speak about a Nordic Landrace. Knowing their relations to the Icelandic goat would be of interest.

Breed situation of horses, pigs and rabbits

Table 4 shows the breeds of three species. Several native horse breeds have become endangered (Jutland and Frederiksberg in Denmark, Döle and Nordland in Norway, worktype of Finnhorse in Finland), because of the decreased demand for working horses. In some of the earlier working breeds, trotting or riding lines have been developed, helping in the maintenance of the breeds themselves. However, it is not clear, whether these types of horses suit to the forest and fieldworks, in case these become topical again. Hence, the working types deserve to be saved. Some breeds (e.g. Norwegian Döle, North-Swedish) are considered to be similar and related, and there has been exchange of material between them. The Icelandic horse is the only breed, which still has the ability for ambling pace, and can also be considered a live gene bank, because of its 1 000 years of isolation. It has spread to all Nordic countries. The Norwegian Fjord horse is found also in Denmark, Sweden and Finland. Iceland obviously is responsible for the conservation of its own breed and Norway for that of Fjord horse.

In pigs, landrace and Yorkshire occur in all the Nordic countries, and since genetic material has been exchanged between countries, the breeds could be considered Nordic ones and are not threatened as breeds. However, the rapid genetic changes taking place in them give reasons to preserve genetic material for the times, when the task of

Table 4. Conservation needs of Nordic horse-, pig- and rabbit breeds.

Species	Country	Number of breeds needed for conservation			
		Whole breed	National type	Within breed	None
Horses	Denmark	2	–	–	20
	Finland	1	–	1	17
	Iceland	–	–	1	–
	Norway	2	–	2	14
	Sweden	–	–	2	15
	Total	5	0	6	66
Pigs	Denmark	1	–	2	2
	Finland	–	–	2	2
	Norway	–	–	2	2
	Sweden	–	–	2	2
	Total	1	0	8	8
Rabbits	Denmark	2	–	–	1
	Norway	2	–	–	–
	Sweden	1	–	–	–
	Total		0	0	1

pigs will again be to convert uneatable material to food for humans. A division of labour or collaboration in this activity is well-founded. There is only one Icelandic pig material based on imports of several breeds at the beginning of 1900s and kept unselected which might deserve conservation, in order to give possibilities to develop fatty pigs eating cheap materials.

There are several meat rabbit breeds endangered in three countries.

Breed situations of poultry and bees

Table 5 shows the situation in laying hens, ducks, geese and bees. Each Nordic country has some native layer hens left. All of them need special attention, even though the situation has improved in two decades. The Norwegian Jaer has a sex-linked genetic factor for cross-striped feathers, making it auto sexing. In the main layer breed, White Leghorn, a need for conserving genetic variation for future use has been seen in most of the Nordic countries, because of the heavy concentration on few commercial hybrids. The possible need to abandon cage management has increased motives for this.

There are also native stocks of ducks and geese in several countries. The same concerns bees, in which a North-Swedish stock of brown bees has been considered worth of conservation, because of its resistance to cold.

Situation of fur animals

The Nordic countries are important producers of furs, because of their natural conditions. Conservation problems

Table 5. Conservation needs of Nordic poultry and bee breeds.

Species	Country	Number of breeds needed for conservation			
		Whole breed	National type	Within breed	None
Layer hens	Denmark	3	–	1	3
	Finland	1	–	1	3
	Iceland	1	–	–	3
	Norway	1	–	1	3
	Sweden	2	–	1	3
	Total	8	0	4	15
Ducks	Denmark	2	–	–	–
	Sweden	2	–	–	–
	Total	5	0	0	0
Geese	Denmark	2	–	–	–
	Finland	–	–	–	1
	Norway	2	–	–	–
	Sweden	2	–	–	–
	Total	6	0	0	1
Bees	Denmark	–	–	–	4
	Finland	–	–	–	1
	Norway	–	–	–	1
	Sweden	1	–	–	1
Total		1	0	0	7

have been discussed in a special working party of the SAAS's subsection for fur-animals. The species used are fox, mink, polecat and raccoon dog. Even though these can be found from the nature any time, their conservation is well-founded from both the cultural and economic viewpoints. Maintenance of live populations of various mutant types, which are not of topical interest, is important, since the fashion can change very rapidly. In Norway, conservation of the White Polar fox was found necessary, in order to be able to produce crosses of it with Silver fox. One has discussed also a coordinated activity in the maintenance of mutants, but it has been difficult to find useful ways for dividing the labour, since the economic interest at the time of a new fashion is very great.

Follow-up of the development of conservation methods

WPAGR has been aware of that freezing of bull semen had been possible since the 1950s and that several AI societies had semen from old bulls, even of landraces. It has tried to follow up the development of both semen and embryo freezing techniques with regard to cost and efficiency in all species of farm animals. In 1981 it initiated a literature study in S on freezing embryos for conservation of AGR (Wilhelmsson and Sylvén, 1981), and has had a couple of its meetings in the Institut of Reproduction of the Danish Vet. & Agri. Univ., which was developing methods for embryo freezing. In 1983 it tried to get joint Nordic finances for a study concerning possibilities to freeze embryos from fur-bearing animals. The techniques for obtaining, *in vitro* culture and fertilization of oocytes from slaughtered females have already well developed and will improve possibilities to embryo conservation, without needing super ovulation of donors. The development of gene technology has opened possibilities for conserving DNA concentrated tissues and cells (e.g. semen) for later studies of the genes of breeds and individuals, and for isolation and gene transfer in the future (Brem, 1990). DNA has the advantage, that it is a chemical, which can be safely transferred from one country to another without disease risks.

The advantages and disadvantages of live animals, frozen semen and embryos, listed by the EAAP working party (Maijala *et al.*, 1984), have been taken into account in planning conservation of different species. The availability of many-sided stores of frozen semen helps in avoiding inbreeding in gene bank animals, and in getting along with rather small numbers of females. The existence of live animals is important for maintaining the interest in the breed and gives opportunities to study its various traits any time. Three different groups of motives have been considered: A = economic–biological, B = scientific and C = cultural–historical. The number of people working on the basis of C-motives has increased. These are ready to invest mental and financial resources to conservation of some breed(s). Animal geneticists are mainly interested in the A- and B-motives. The WPAGR has tried to get the different groups of people to collaborate with each other. This would make the conservation of a breed to serve that of genetic variation and help the conservers to avoid unnecessary inbreeding and economic losses. Unplanned mating and use of very limited numbers of males do not help conservation of genes.

Nordic data bank on AGR

In 1985, WPAGR started to plan an information centre (data bank) on an Inter-Nordic level, based on standardized forms for collecting information about breeds. Collection of all information registered in the countries to the data bank for handling and preserving makes the bank able to supply actual users with needed information. It would also be favourable, as several Nordic breeds cross the borders and some breeding organizations exchange breeding males and semen. All data in one bank simplify calculations of genetic connections and differences between populations. The bank was placed to the Agric. Univ. of Norway and is based on three main types of forms:

I. *Origin and status*: This is common for all species and breeds and gives general information of the breed.
II. *Breed qualities*: This gives breed characteristics and has thus to be somewhat different for different species, but the same for breeds of the same species.
III. *Individual qualities*: This gives similar information on individuals conserved as live animals or in the form of frozen semen, egg cells or embryos. This information is important for later utilization of stored material. The form is the same for breeds of the same species, but specific for each species.

Each piece of information is located at a given numbered place on the form, so that the numerical or coded information can be handled and understood independently from the language. Some of the rubrics are to be filled in with numbers or gene symbols, others with an X-tick. The rubric texts can thus be translated to the five different Nordic languages or to English without causing problems for data processing. Remarks and added information can, on the other hand, be in a language acceptable for further handling.

The realization of the data bank was put off in order to coordinate the forms with those of the data bank of European Association of Animal Production (EAAP), placed in Hanover, Germany. The comparisons caused some modifications in the forms. All rubrics in the EAAP forms were included in the Nordic forms with the same address numbers. In 1988, the EAAP data bank became a Global Data Bank supported by FAO. The EAAP/FAO forms concern only six species and only breeds, while the Nordic ones comprise 18 species and cover also individual animals, semen and embryo stores.

There have been some technical problems in applying the database program of the EAAP/FAO bank in small computers, and hence the application has been delayed. The delay has not hindered gathering of data and is expected to be compensated for by the advantages the coordinated program will give.

Information activities

WPAGR has considered that effective spreading of information of breeds and of their conservation, to both authorities and interested people, is important for successful work. Hence, it has published reports in scientific journals and congresses, organized a seminar and participated in seminars arranged by the national working parties (Denmark and Norway in 1988, Sweden in 1991. These have also participated in agricultural shows, prepared films and TV programmes, published leaflets, popular articles and post cards, and given talks in various meetings.

WPAGR prepared a book (144 pages) about farm animals in Nordic countries (Gjelstad, Kolstad and Maijala, 1993), with the following contents: Farm animals in service of mankind, development of productivity, Nordic farm animals in text and figures, motives for conservation, conservation methods, national conservation activities and Nordic collaboration on conservation. The contents reflect the work performed, and the problems discussed by WPAGR during a decade.

Progress made in conserving genetic materials

Live animals

Live animals of endangered native breeds have been placed in agricultural schools (Denmark, Norway, Sweden) and museums (Denmark, Norway), nature reserves (Sweden), prison farms (Finland), animal parks and private farms. In Norway, the agricultural museum has made contracts with agricultural schools about maintenance of cow samples of endangered breeds, plans for breeding, feeding, management, veterinary hygiene, recording, mediating animals, etc. Private interest in preserving original breeds has increased considerably in all the countries in the 1980s, and societies of interested people have been established for several breeds. In several endangered breeds of cattle it has been difficult to find purebred animals, and hence animals having 50–87.5 percent of their genes from the breed in question have also been saved (Blomqvist, 1989). Active search and registration have helped in finding new purebred cows in several breeds, which were almost extinct (e.g. 35 Westland Red Polls in Norway in 1986, but 67 cows in 1989). However, the genetic background is often rather narrow, rendering avoidance of inbreeding difficult. In some native breeds, which had some thousands of animals left at the time of committee report, the numbers have continued declining.

The Norwegian gene bank for poultry, established in 1973, got a new premise in 1983, and maintains small non-active lines of layer hens, which have traits of interest for future breeding or cultural–historical importance (e.g. Jaer hens). The intention is to place also small populations of White Norwegian goose in the bank, which is run by the Norwegian Poultry Breeders' Assn.

Frozen semen

Old frozen semen doses have been preserved, if available, and semen has been frozen from new reasonably pure males after they have reached sexual maturity. This has been important for being able to use many males in each breed for mating and for avoiding the use of single live males to all the females of a herd. The number of bulls, from which there was semen stored, was about doubled in several Norwegian native breeds from 1984 to 1989 and in the east Finnish cattle from 1983 to 1991. In the north Finnish cattle the number has increased from 0 to 13 in the same period. The Swedish and Icelandic rules of saving 100 resp. 30 doses from each AI bull, irrespective of whether the breed is endangered or not, have meant considerable increases in the diversity of semen banks for possible changes of future needs.

In pigs, the long-term storage of one ejaculate from each boar in Denmark since the 1970s means a continuous increase in banked material. Finland has semen from several boars from the time before the Halothane testing and culling for stress susceptibility started in the 1970s. Ram semen is frozen from three counties in Norway, and Finland has semen from six Finnsheep rams frozen in the first part of the 1980s. In Norway, 50 doses of semen had been frozen from each of 50 goats in 1976–1983, i.e. a total of about 2 500 doses. Most of the Nordic countries have frozen semen from cockerels, but not yet for conservation purposes. This kind of conservation is not as important in poultry as in mammals, since the male is the homogametic sex and the share of sex hormone of the total genome is relatively large.

The popularity of AI in horses has made it possible to make plans for freezing semen from working horses for conservation purposes. The same concerns foxes.

Frozen embryos

Freezing embryos of endangered cattle breeds has started in at least two endangered breeds in both Norway and Finland, and Denmark and Sweden have the technical readiness. In Finland there are also frozen embryos from Finnsheep since 1984.

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The conservation values of Yakutian Cattle

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Summary
The loss of biodiversity has become a major environmental issue during the course of the twentieth century. Numerous indigenous farm animal breeds have been replaced by commercial breeds in agricultural production processes in industrialized countries, sometimes resulting in complete breed loss and at other times placing the breed in an endangered status. Loss of breeds occurs mainly due to the striving for more intensive production, which often means that indigenous farm animal breeds are kept in conventional production only in marginal agricultural areas. One such endangered breed is the Yakutian Cattle, an indigenous Siberian cattle breed that is kept in the Russian Far East. The cattle have a low output but valuable characteristics that confer adaptation to the northern environment. This article addresses the socio-cultural and political context of conservation of the cattle at different levels in society. The conservation of animal genetic resources is embedded in the international agenda, and the Russian Federation has ratified conventions to protect them. The conservation is de facto organized at the republic level. The local communities carry out the conservation in practice by keeping and maintaining the cattle, although the conservation was initiated by the scientific community. We suggest that the conservation of Yakutian Cattle is based on national and local interests, rather than on global conventions on biological or cultural diversity. Furthermore, the reasons for conservation are different at different levels, which constitute both an advantage and a challenge for the future.

Keywords: *animal genetic resources, biodiversity conservation, community-based management, indigenous breeds, sustainable community development*

Résumé
Au cours du XX^{ème}siècle, la perte de la diversité biologique est devenue un problème d'environnement majeur. Dans les pays industrialisés, de nombreuses races indigènes d'animaux d'élevage ont été remplacées, dans les processus de production agricole, par des races commerciales. Ce remplacement a entraîné parfois la perte totale de la race et parfois la menace d'extinction. La raison principale de la perte des races est la recherche d'une production plus intensive. Cela signifie souvent que les races indigènes d'animaux d'élevage ne sont maintenues dans la production conventionnelle que dans les zones agricoles marginales. Un exemple de ces races en danger est représenté par les bovins de race yakoute, des bovins indigènes de la Sibérie qui sont élevés dans l'Extrême-Orient russe. Ces bovins ont un rendement faible, mais des caractéristiques précieuses qui les rendent tolérants aux conditions environnementales du nord. Cet article aborde le cadre socio-culturel et politique de la conservation des bovins aux différents niveaux de la société. La conservation des ressources zoogénétiques est inscrite aux programmes des conférences internationales, et la Fédération de Russie a ratifié les conventions qui les protègent. La conservation est de fait organisée au niveau de la république. Elle a été lancée par le milieu scientifique, mais les communautés locales la mettent en pratique, en élevant et en préservant les bovins. Nous suggérons que la conservation des bovins de race yakoute se base sur les intérêts nationaux et locaux, plutôt que sur les conventions mondiales en matière de diversité biologique ou culturelle. En outre, les raisons de la conservation sont distinctes aux différents niveaux, ce qui représente en même temps un avantage et un défi pour l'avenir.

Mots-clés: *conservation de la diversité biologique, développement communautaire durable, gestion communautaire, races indigènes, ressources zoogénétiques*

Resumen
La pérdida de la biodiversidad se ha convertido en uno de los problemas medioambientales más importantes del siglo XX. Numerosas razas autóctonas de animales domésticos han sido reemplazadas por razas comerciales en los procesos de producción agrícola de los países industrializados, a veces, dando como resultado una pérdida completa de la misma y, otras, situándola al borde de la desaparición. La principal razón de la pérdida de razas es la lucha por una producción más intensiva, que, a menudo, va unida a una producción convencional con las razas autóctonas de animales domésticos, restringiendo a éstas y su cría a zonas agrícolas marginales. Una de estas razas en peligro de extinción es la raza bovina Yakutian, una raza autóctona de ganado siberiana que se mantiene en la zona más oriental de Rusia. La producción de este tipo de ganado es muy baja; sin embargo, posee características que le confieren una mejor adaptación al medio ambiente del norte. Este trabajo aborda el contexto socio-cultural y político de la conservación del ganado a diferentes niveles de la sociedad. La conservación de los recursos zooognéticos es un tema de calado en la agenda internacional, y la Federación Rusa ha ratificado las convenciones para la protección de los mismos. La conservación es de hecho organizada a nivel de república. Las comunidades locales llevan a cabo, en la práctica, la conservación y el mantenimiento del ganado, aunque la

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conservación se inició por la comunidad científica. Se apunta que la conservación del ganado de Yakutian se basa más en los intereses nacionales y locales, que en las convenciones mundiales sobre la diversidad biológica o cultural. Por lo tanto, las razones para la conservación son diferentes en los distintos niveles, constituyendo una ventaja y un reto de cara al futuro.

Palabras clave: *conservación de la biodiversidad, desarrollo sostenible de la comunidad, gestión basada en la comunidad, razas autóctonas, recursos zoogenéticos*

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Introduction

Conservation of animal genetic resources (AnGR)

There are many reasons for the conservation of indigenous breeds listed by researchers and conservation organizations, as well as international conventions (Notter, 1999; Mendelssohn, 2003; Gandini and Villa, 2003; Verrier *et al.*, 2006; Anhtempelman and Cardellino, 2007; Oldenbroek, 2007, pp. 19–22; Soini, 2007a). However, multifaceted reasons for conserving indigenous farm animal breeds and political will to carry out the conservation are not necessarily enough to safeguard the farm AnGR in reality. There is usually a long period of transition from political will and interests to real implementations of conservation programmes at the grassroots level, which makes the conservation of indigenous farm animal breeds and their genetic resources challenging (Tamminen, 2010).

Zimmerer (2006, pp. 3–6; 2007) has noted that conservation of biodiversity has new characteristics as a result of globalization. It has not only accelerated the loss of biodiversity, but also the growth of environmental globalization introducing new means and actors in biodiversity conservation (Zimmerer, 2006, p. 1). Therefore, it is increasingly important to recognize the spatiality of conservation, which takes place at different scales. With spatiality Zimmerer (2006, p. 9) refers to a concept that helps us to see environmental spaces and configurations in which the physical extent is fused with social intent. Usually, the challenge of environmental conservation is that the scales of the environmental problem and the solutions are incompatible (Kaljonen, 2006; Soini, 2007b). Therefore, it is important to analyse and identify the distinct spaces and their interaction. Owing to the diversity of spaces and scales, the conservation of indigenous breeds as an environmental issue is about the *governance of conservation*.

In environmental policy the concept of governance suggests that we look beyond government, towards new partnerships, as a way of dealing with the shortcomings of top-down management (e.g. Berkes, 1999). Kooiman (2003) recognizes three models of governance. *Hierarchical governance* is characterized by the state intervention. *Self-governance* can be used to describe a people or group being able to exercise all the necessary functions of power without intervention from any authority that they cannot themselves alter. *Co-governance*, in turn, consists of collaboration and interplay among different actors suggesting that people whose livelihoods are affected by management decisions should be able to participate in decision making. Therefore, it is suggested that self-governance would increase compliance and empowerment leading to more legitimate, socially and culturally acceptable management measures (Kooiman, 2003).

The case of Yakutian Cattle

In the Far East of Siberia there are small populations of Yakutian Cattle, which are the only surviving cattle originating from the Siberian ox taurus cattle (Kantanen *et al.*, 2009). The changing institutional and political environment, as well as globalization and modernization, constitute a continuous challenge to the general livelihood system in the region, and for the conservation of the cattle in the future.

The ultimate aim of this article is to examine the spatiality and the governance of the conservation of the Yakutian Cattle. We will first examine how the conservation of the Yakutian Cattle has emerged and evolved at various spatial scales: in global biodiversity policy, at the Union, Federation and republic level, in the Eveno-Bytantay district and in the media. Second, we will ask how the conservation of the cattle is promoted and argued for by various actors at different spatial scales. Finally, based on the results, it is possible to discuss the governance of the conservation of the Yakutian Cattle.

The Yakutian Cattle in the three villages of Eveno-Bytantay district

The Yakuts migrated[1] with their horses and cows in several waves to the central Yakutian regions after the ninth century, introducing the tradition of raising cattle into these northern areas, which were traditionally settled by peoples living from reindeer herding and hunting.

[1] The migration trail of the Yakuts, and that of their cattle, is still shrouded in uncertainty, but the most common theory is that the people and their cattle came from south-west Asia or Mongolia and stayed by Lake Baikal for some time (Crate, 2006, pp. 43–48).

The Yakuts were transhumant, moving from wintertime dwellings to summer pastures, following the needs of their cattle and sharing their houses with the animals (Basharin, 1962).

Until the 1930s, native Siberian cattle existed in all central Sakha, but the collectivization brought changes to cattle husbandry. The replacement of the Yakutian Cattle with more productive animals decreased the numbers of the original breed. Already by the late 1950s, Yakutian Cattle existed only in the remote northern territories, where the transport connections were poor and distances long (Romanov, 1959, 1984).

Currently, the population of about 1 000 head of Yakutian Cattle exists in the Eveno-Bytantay district, in three villages, Batagay-Alyta (Sakkyryr), Kustur and Dzhargalakh, which are located above the Arctic Circle, approximately 1 000 km to the north of the capital of the republic, Yakutsk. Map 1 shows the location of these villages in the Sakha Republic. Since the collapse of the Soviet Union, most of the cattle are privately owned. The remainder are located in the state-owned enterprise *Bytantay* (until 2005, *Yakutsky skot*) that keeps Yakutian Cattle in the villages of Kustur and Batagay-Alyta. Another state-owned farm for research work is located in a village in Gorny district in Uluu-Syhyy near Yakutsk, and has operated since the mid-1990s.

The Yakutian Cattle are black, red or piebald with white markings on the head and other parts of the body. They are characterized by their small size, deep but relatively narrow chest and short, firm legs. They possess a solid trunk and thick coat, as well as efficient thermoregulation, quick formation of subcutaneous fatty tissue and low metabolic rates at low temperatures. The head of the animals is typically short but broad. The live weight of cows ranges from 350 to 400 kg, and that of the bulls from 500 to 600 kg. On average, the breeding bulls stand 121 cm high. The current average annual milk yield of the cattle breed is 1 000 kg, and the milk has a high percentage of fat and protein, 5.03 and 4.69 percent, respectively, on an average (Kantanen *et al.*, 2009; Tapio *et al.*, 2010).

Kantanen *et al.* (2009, pp. 37–39) reported that the conservation value of the Yakutian Cattle is high in genetic terms. Molecular genetic analysis has revealed that due to a long period under extreme environmental conditions, geographic and genetic isolation, the purebred native cattle breed has a high conservation value for the maintenance of cattle diversity.

Moreover, it has been found that the cattle constitute an important part of local livelihood system from the social, economic and cultural points of view (Soini and Partanen, 2009). Since the 1950s, there have been various attempts to preserve the cattle. These activities culminated in the law on conservation in 2001, which among other measures guarantees economic incentives for keeping the cattle. Besides the conservation of live animals, the basis for *ex situ* conservation has been established and genetic research is conducted.

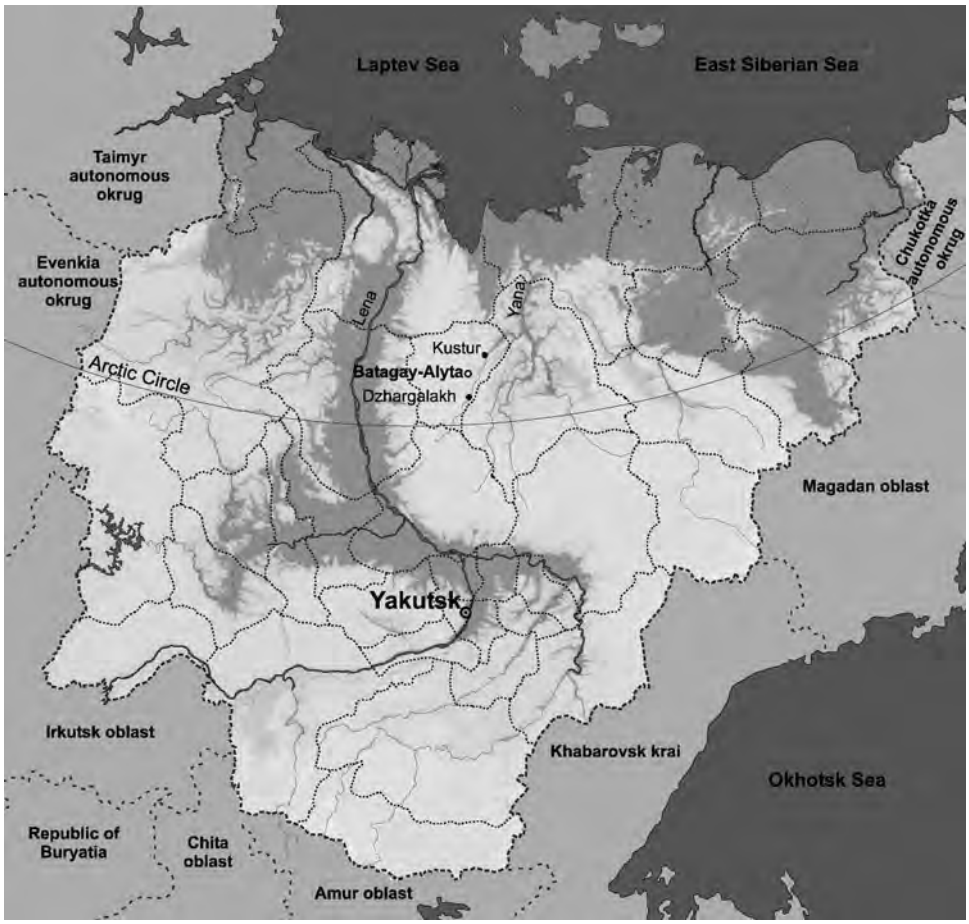
Material and methods

Our analysis aims to investigate the socio-cultural and political context of conservation of the Yakutian Cattle that is transmitted to us through various sources concerning reasons for the conservation. The various sources of information were used to verify and falsify information provided, and to create a coherent understanding of the values of the Yakutian Cattle. We assume that attitudes are intertwined both in the direct and indirect social and cultural contexts as well as in individuals arguing them (Vesala and Rantanen, 2007, p. 54). It is also essential to understand the situation in which the information we gathered was created e.g. in an interviewing situation or publishing media representations. Understanding the situation is essential for understanding different phenomena, attitudes and values that the members of a certain society share (Goffman, 1986).

The research material consists of various documents on the history of Russia and in particular of Siberia, modernization of agriculture and emergence of environmental awareness related to AnGR. We have also used coeval literature written by scholars who were engaged in the conservation of Yakutian Cattle already during the Soviet time. In addition, there are political programmes and laws enacted by the United Nations (UN), the Soviet Union, the Russian Federation and the Yakut ASSR or Sakha Republic, as well as 71 interviews made during our fieldwork. Three distinct groups of interviews can be identified: First, *the local residents*,[2] who either have a subsidiary farm or work at the state farm and have a lot of experiential, traditional or local knowledge related to the cattle husbandry, and also other residents, who work in other occupations and who do not have any cattle themselves. Second, *the specialists and experts in the local administration and in cattle breeding, production or research*. They can be termed as local certified experts[3] whose main concern is how to organize and develop cattle husbandry in the district and to meet all the technological, financial and social requirements, and also conduct the scientific experiments required by the republic. Third, *the researchers, politicians and administrators in Yakutsk*, who perceive the issue from the republic's, and even a wider point of view, but are not necessarily very familiar with the realities of the three distant villages. The interviews are classified in Table 1. The interviews were conducted in Russian and translated into English. In addition to the interviews, we rely on observations made

[2] The total population of Eveno-Bytantay district was 2 778 persons in 2007. There were 1 746 people living in Batagay-Alyta, 747 in Kustur, 280 in Dzhargalakh and five people in Aly (Kopoteva and Partanen, 2009).

[3] See e.g. Fischer (2000) for defining local and traditional or ordinary knowledge and Collins and Evans (2002) for certified and uncertified experts.



Map 1. The Sakha Republic (map by Jari Johansson).

Table 1. Number of interviews.

	Republic level	Local level	Total
Specialists and experts	14	17	31
Cattle keepers	0	12	12
Other residents	0	28	28
Total	14	57	71

by a multidisciplinary research team during our fieldwork in spring 2005 in the three villages and in Yakutsk.[4]

Moreover, newspaper articles published by two Sakha newspapers in 2003–2005 were analysed: *Yakutia* (Y) published in Russian and *Sakha Sire* published in Yakutian and translated into Russian by local students. The media plays a significant cultural and social role as it produces and transmits different public awareness messages. It also reflects the societal reality and common currencies already existing in the society (McQuail, 1992; Kunelius, 2001). The research material includes newspaper articles dealing with the Yakutian Cattle and the current development of traditional agricultural livelihoods in the Sakha Republic. The media representations are studied with the help of a text analysis, and the results are dealt with in a wider societal context.

[4] The research team consisted of the following researchers in addition to the authors: Prof. Leo Granberg (sociology), Lic. Sc. Inna Kopoteva (human geography), M.Sc. Eeva Pääkkönen (cultural anthropology) and M.Sc. Anu Osva (artist).

The spaces of conservation of the Yakutian Cattle

Conservation of local breeds in the Soviet Union and Russian Federation in the frames of global biodiversity policy

Early steps of AnGR conservation in the Soviet Union

In the early 1970s, the erosion of farm AnGR raised international attention for the first time. The conference of the UN on the Human Environment, held in Stockholm in 1972, recognized that conservation is the most crucial part of any genetic resources programme, and therefore the conference recommended that governments, in cooperation with the Secretary-General and the Food and Agriculture Organization (FAO) of the UN, make inventories of the genetic resources most endangered by

depletion or extinction (Report of the United Nations Conference on the Human Environment, 1972).

The inventory of farm animal breeds that were either endangered or at risk of becoming endangered was also made in the Soviet Union in the mid-1970s. Several cattle breeds were included on the list, including Yakutian Cattle, comprising 300 dairy cows. The Soviet Union made recommendations to conserve the genetic resources of their endangered farm animal breeds (Romanov, 1984, pp. 10–11). According to Romanov (1984),[5] the conservation policy had two main goals: to support regional policy and to utilize the genetic resources of Yakutian Cattle in breeding.

The failures in the modernization of Soviet agriculture, such as continuous problems in productivity, enabled the development of farm AnGR in the Yakut ASSR from the mid-1970s (Plan plemennoy raboty, 1981; Romanov, 1984). Earlier, the small size of the Yakutian Cattle had been regarded as an undesirable attribute by agricultural modernizers (Smith, 2006, p. 81). After the Stockholm Conference, the Soviet genetics researchers legitimized the conservation of Yakutian Cattle relying on the arguments underlying international development in the conservation of genetic resources (Romanov, 1984). The goals of Soviet agricultural policy had conventionally not only been about producing food but also about geopolitical and environmental issues, the latter especially in terms of overcoming environmental barriers such as harsh climatic conditions in most parts of the country (Smith, 2006, pp. 5–6).

In the late 1970s and early 1980s, agricultural productivity decreased. It was argued that among other issues one of the reasons for this was the poor state of animal breeding in the country (Naukhatsky, 1996, pp. 60–61, 65, 116, 123). The Soviet Union aimed to improve and intensify agricultural production by creating new farm animal breeds of high quality in terms of production. The special aim of agricultural production in Siberia was to provide local people with local food and to promote self-sufficiency (Prodovol'stvennaya programma SSSR, 1982, pp. 55–57, 64; Materialy XXVI s'ezda KPSS, 1981). The coming years did not bring any major relief to the difficult agricultural situation (Neuvostoliiton maatalousuudistus, 1989, pp. 7–10).

Conservation of AnGR in the Russian Federation

The question of AnGR advanced internationally as FAO developed activities in cooperation with UNEP during the 1980s. In particular, FAO provided training in the establishment of gene banks (Wiener, 1989).

[5] Pjotr Apollonovitch Romanov was a genetics research scientist highly committed to the conservation of Yakutian Cattle and working at all scales of conservation, from the federal to the local level. He published studies concerned with the genetic resources of the cattle already in the 1950s and organized conservation in the 1970s. He perished in a hunting accident in the early 1980s.

According to our interviews, there are currently some research projects at the federal level that aim to study breeds that are in danger of becoming extinct, and they are processing a nationwide conservation programme for endangered breeds. There is also a federal law that regulates animal breeding, and a law specifically directed at endangered breeds has been planned (researcher in Yakutsk, interview 67). The federal laws direct the administrative frameworks for the conservation work on genetic resources. In 2002, the Russian Federation enacted the Federal Law on Environmental Protection that defines the roles of different subjects of the Russian Federation in nature conservation work (Silfverberg *et al.*, 2004, pp. 14–16). Consequently, in the case of Yakutian Cattle, the Sakha Republic is in a very important position and it has worked for the conservation of the genetic resources of Yakutian Cattle within the frameworks set out by the Federation (Agreement, 1995).

Conservation of the Yakutian Cattle at the republic level

The turbulent years of system change

A substantial impact in conservation during the 1980s was the establishment of a research station for Yakutian Cattle in Batagay-Alyta. This was achieved according to the plans to conserve the cattle breed that were made in the late 1970s. The head of the research station was P.A. Romanov who had also been the initiator in the beginning of the conservation. According to our interviews, he had been the main actor in convincing the party officials at the republic level of the need to safeguard the breed. Although the plans to conserve the cattle had been more ambitious, this provides an example of state intervention on the conservation of the Yakutian Cattle.

The cattle breed was also conserved by means of self-governance; in other words, the people living in the local communities had the opportunity to participate in the decision making some years later. The privatization of agriculture started in the late 1980s and accelerated in the 1990s at the federal level. At the time of the privatization process, Soviet state authorities were losing their influence, and the former chairmen of collective farms mainly held the knowledge about new legislation designed at the federal level (Lindner, 2006).

According to our interviewees, the state farm in Eveno-Bytantay district collapsed in 1993–1995, and there were gatherings organized for the local people to discuss the matter with the administration. The animals were to be divided among the people according to years in service, and therefore mainly elder people together with some local administrators were in favour of dividing the cattle (local expert, interview 5). As noted above, the importance of Yakutian Cattle was already recognized at the republic level and the Yakutian Cattle were saved, although great numbers of farm animals had been slaughtered in connection with the privatization. Following Granberg and

Kopoteva (2009), the people in favour of conserving the cattle breed at republic and local levels probably influenced the decision.

The cattle were also safeguarded by the republic and the scientific community by transferring some of them to the southern parts of the Sakha Republic, Gorny district. The cattle are kept in a state farm for research purposes, and simultaneously as a living gene bank to secure the maintenance of their genetic resources. Hence, the state intervened to keep the cattle pure-bred and live in the turbulent years after the collapse of the Soviet system.

The law on conservation of Yakutian Cattle

In 2001, the conservation reached a new phase when the Sakha Republic enacted a law on the conservation and use of the cattle. It elevated the Yakutian Cattle to the status of an endangered breed (researcher in Yakutsk, interview 67). The law is unique, even in the global context. The law aims at promoting the genetic diversity of the breed, keeping the breed pure and preserving it for future breeding. It consists of regulations concerning the insemination, registration and farming of the cattle as well as of financial support designed for the public and private farms that keep the Yakutian Cattle (Zakon ot 7 iyunya 2001 goda 3 No 291 – II).

The financial support is directed at the animal keepers according to the number of cattle they manage. It also includes buying their milk and meat products. The law guarantees both tax and credit privileges for the cattle keepers. Another factor in the support system is the financing of scientific research work on the conservation. It is intended that the work be financed by the republic, using local budgets together with income from the farms (Zakon ot 7 iyunya 2001 goda 3 No 291 – II).

The conservation programme included in the law works at the republic level, but it is formally part of the federal programme that aims at developing rural areas (administrator in Yakutsk, interview 65). Furthermore, the presidential programme for social and economic development of villages has been working since 2002 in Sakha Republic and addresses the conservation of Yakutian Cattle (researcher in Yakutsk, interview 67). In practice the Ministry of Agriculture in Sakha initiated the funding for the conservation process, and it is the Agricultural Institute that takes care of the practical responsibilities, with the support of the Ministry. Each district has a branch within the Ministry of Agriculture and takes care of accounting and budgeting for cattle and reindeer production (local administrator, interview 1).

Genetic value

Many of our interviewees in Yakutsk emphasized that the main objective of conservation was to preserve the genetic resources of Yakutian Cattle to be exploited in cattle breeding for the republic. From the republic's point of view, agricultural production should be increased, and the Yakutian Cattle represent valuable material for cross-breeding. Consequently, only after ensuring conservation of the genetic resources could the focus be on development of production.

As with the international experts in conservation of the Yakutian Cattle, our interviewees in Yakutsk favoured *in situ* conservation in Eveno-Bytantay district. They considered that the distant and isolated location guarantees the purity of the breed. The long history of cattle breeding within the same area was respected, and it was considered important to continue breeding in the same geographical district from the genetic research point of view. Researchers and politicians had also realized that it is not possible to increase the numbers of cattle in Eveno-Bytantay because of the limited hay production and feeding possibilities. They also considered general socio-economic conditions critical for the conservation of the cattle. For that reason many of them highlighted the importance of improving the socio-economic conditions both in the state farms and in the villages.

Cultural value

As to the researchers and politicians, many of whom were Yakuts themselves, the cultural value of the Yakutian Cattle primarily represented preservation of a traditional way of life and the conservation of a cultural heritage related to the cattle. Cattle were also needed for research, which would provide new information about the history of the Sakha people. Thus, besides the value the Yakutian Cattle might have for cattle breeding, the cattle were seen as a means to preserve and strengthen the cultural identity of Sakha people in the republic.

Conservation of the Yakutian Cattle at the local level

Cattle – food and income

The local people, the residents keeping cattle and the local administration and extensionists in the field of cattle production, play a very important role in the conservation of the cattle. At the local level, distinct arguments were mainly based on economic reasoning but the role of the breed as part of their cultural heritage and social structure were also emphasized. The local people also knew that the cattle were genetically unique and adapted to the local environment.

The most obvious value to the local residents of the Yakutian Cattle was related to their direct use in local food production. Milk products and meat provided an important share of the diet of local people, in particular during summertime. Besides foodstuffs, the cattle provided other products and services to the local community, for example, manure for the construction of cow houses, fertilizer for the greenhouses and gardening.

The subsidies for milk and credits for buying cattle had made many people from various social groups start cattle

raising. The additional incomes were used for purchasing or exchanging for other goods and services they needed. Thus, the cattle provided a way to ensure a better future for their children, and a sort of long-term social insurance for the whole family, many of them seemed to think. Some people kept the cows because of the support system (local administrator, interview 41).

Cattle – social insurance, inclusion and interaction

The social aspects of cattle production, as for local agriculture in general, extend to cover local employment, social status, social cohesion, and social inclusion and exclusion. Cattle provided supplementary income for many households or even entire livelihoods for people who were otherwise unable to make their living.

However, there were also social problems related to the work with the cattle. The working conditions were hard both in the private households and state farm, where they had problems with delayed payment of the salaries in the mid-2000s resulting in the reduced well-being of the cattle. The main concern was related to the bad condition and poor level of mechanization of the cowsheds and lack of mechanical devices for the haymaking.

The cattle production with all its implications extended to a wider social sphere, to the kin and to the local community at large (see also Crate, 2006). Working together, cooperating in various phases of work and the allocation of material resources and know-how contributed to the formal and informal networks, which is of crucial importance for the formation of social capital (Pretty, 2003) and thus, for the local development.

Cattle production has also been responsible for both crossing and setting borderlines between the main nationalities, the Yakuts and the Eveny. Traditionally, reindeer herding was mainly a livelihood of the Eveny, whereas cattle raising was the means of livelihood of the Yakuts, but recently many Eveny have also started to keep cattle.

Cattle – food, traditions and cultural landscape

Considering other cultural values of local breeds identified by Gandini and Villa (2003), the cattle products in the local food culture and gastronomy have persisted partly because there has been no real choice in supplying milk products. However, it was not only the nutrition aspect, but also the gastronomic characteristics, the taste of the meat and fat content of the milk, which were emphasized by the local residents. One should note that due to the isolated location of the area there was only little choice for the fresh food products.

In addition to the food culture, the traditional knowledge related to cattle breeding and building a cowshed suitable for local conditions, was known among the population. This culturally embedded local knowledge constitutes an essential part of the "memory bank" that is needed for the conservation of genetic resources in the district (Nazarea, 1998).

The cattle is also a part of traditional rituals, e.g. funerals when, for men, bulls or horses and, for women, cows, calves or bullocks are butchered to provide the dead with means of transport (Pääkkönen, 2009, p. 62).

The Yakutian Cattle husbandry has a wide range of impacts on the landscape of present-day villages in the form of cowsheds, grazing lands, manure stocks, haystacks, fences as well as the cattle themselves, which frequently walk along the streets of the villages. Landscape elements related to the cattle were displayed almost everywhere in the village; the cattle are a part of the everyday life of the local community and belong to the physical landscape.

The long history of cattle production in the district, a tradition that has lasted for centuries, was highlighted both by the local experts and residents, and they consider it important to continue it. The local experts considered the Yakutian Cattle as a local cultural property or "capital", which gave them a certain status among the rural districts in Sakha.

The conservation discussed in the media

In the Eveno-Bytantay district people seemed to understand the value of their native breed. When asked, they often mentioned having read about the conservation programme from the newspapers. Sometimes their arguments of why the conservation was important seemed very similar, and it is likely that they repeated the official line transmitted by the administration and the media. On the other hand, the local administration and media do not necessarily share their views about the state of affairs (Zassoursky, 2001, p. 158).

The media representations about the Yakutian Cattle focused on the conservation of the cattle, the economic, cultural and genetic significance, as well as on the holistic situation of farming in the republic. The articles were written in connection with current events, and both the newspapers adopted the role of criticizing the authorities and defending the ordinary people.

Although the newspapers were highly supportive of the idea of preserving the Yakutian Cattle for improving cattle production in Sakha, it was debated as to how the conservation should be financed. It was stated that keeping the Yakutian Cattle is not economically profitable.

The Yakutian Cattle were stated to be the only cows that survived in the harsh climate with poor nourishment. Therefore, they were the only cows that could be kept in the far north. Regardless of the low output, it was acknowledged that the cattle enable the residents of the small villages to remain in their homes and keep the area settled. The expenses of keeping the northern areas settled are considerable and after the Soviet era they have to be taken into account more than before. The idea of utilizing the north and its resources does not necessarily include the idea of keeping it permanently

settled (Möller and Pehkonen, 2003, p. 3). Therefore, the animals were seen as the guarantee for the self-sufficiency of the district, which indicates that the main reason to conserve the cattle has not changed from the old times when the remoteness of the district protected the cattle breed from replacement with more productive cows.

According to the media, the most significant achievement of the Sakha people is that they created their own culture of horse and cattle production, and that the severe conditions created the unique Yakutian Cattle. The cattle were often mentioned in the newspapers as a cultural heritage of the Sakha people, and it is possible that the cultural meaning and its emphasis is the easiest way to convince ordinary people about the importance of conserving the cattle. In addition, it was probably meant to result in a defensive attitude towards the cattle among the citizens, and to raise their self-esteem and respect for their way of life. The media is important in the construction process of cultural, local and national identities as it strengthens the feeling of togetherness among its readers (Kunelius, 2001, pp. 168–169). In the current post-Soviet time the Sakha people are in general rediscovering their ethnic roots and cultural traditions, which strengthens their ethnic identity (Jordan, 2002, pp. 260–261).

Discussion

Arguments for the conservation of the cattle production

By examining the phases of the conservation of the Yakutian cattle we have found various arguments for the conservation of the Yakutian Cattle. These arguments have been summarized in the Table 2. The reasons have been categorized in the genetic, economic, social, cultural and regional political. As we have seen, the arguments differ from scale to scale.

The governance of the conservation of the Yakutian Cattle between the scales

How can the spatiality of conservation of the Yakutian Cattle be assessed from the governance point of view? The beginning of the conservation was initiated and carried out based on hierarchal governance and top-down policy in a similar way as the modernization of agriculture had been some decades earlier.

In the early and mid-1990s, there were signals of self-governance as in the new system the state control was loosened and the voice of local residents was heard in the privatization process. Yet, the state was to intervene in the conservation soon again.

By ratifying the Convention on Biological Diversity (CBD) in 1995, the Russian Federation divided power in the conservation to the regions. The northern parts of the Federation have, nevertheless, lost their status as an ideologically important area (Möller and Pehkonen, 2003, pp. 3). The cancellation of federal subsidies for northern regions and abandoning of Soviet era social programmes that provided even rural areas with large numbers of state jobs have been important factors in the development of the republic (Jordan, 2002, pp. 227–230).

According to Speth and Haas (2006, p. 85), nations are the principal legal actors in environmental policy because they respond to pressure from a number of different actors. This is the case also regarding the Yakutian Cattle. The Sakha Republic is the main financer of the conservation and it is in its interests to develop remote areas and their agriculture as well as to take care of the cultural aspects of

Table 2. Arguments for conserving the Yakutian cattle presented by different actors at various spatial scales.

Arguments/ spatial scales	Soviet Union – Russian Federation	Republic	District/local	Media
Genetic	Conserving genetic resources for the future cattle breeding	Conserving genetic resources for the future cattle breeding	A cattle breed adapted to the local environment	Conserving genetic resources for the future cattle breeding
Economic	Improving the efficiency of cattle production	Improving the efficiency of the cattle production, creating the quality products for export	Food sufficiency of households, additional incomes for the households	Additional incomes for the local residents
Social	Relieving general social problems of the north		Working possibilities, social inclusion, social well-being	Working possibilities
Cultural		Manifesting the history of the Yakuts, scientific interests	Food gastronomy, part of the traditional, way of life and landscape, manifestation of Yakutian culture to the Eveny culture	History of the Yakuts, self-esteem of the people
Regional policy	The north too expensive to be permanently settled	Keeping the region inhabited	To be able to live in the region, to be able to negotiate the rights of the region	Keeping the region inhabited

traditional cattle breeding. The crucial thing is the general socio-economic and political development of the republic. The lack of financial resources has made the conservation of Yakutian Cattle more complicated and there are fears that the new self-governance of districts,[6] including Eveno-Bytantay district, aggravates the situation because the remote areas will largely be left to fend for themselves. In other words, the question of conservation may in the future be in the hands of the district or local level.

Recently, hierarchal governance and state intervention have played a central role in the conservation in the form of the law on the conservation and introduction of subsidies. The law and other conservation activities conducted by the republic may help to conserve the cattle. Our research also revealed that the local people having cattle were viewed by the republic more as objects of conservation than as equal partners in the conservation process.

Therefore, we argue that there is an urgent need for co-governance, sharing of power and increase participatory and community-based approaches in cattle production and conservation activities. That kind of approach would generate trust among the various actors and result in sustainable future for the cattle and the people who are living with them.

Conclusions

Our study revealed that the conservation and existence of the Yakutian Cattle is primarily based on local and national interests, rather than on global ones concerning conventions on biological or cultural diversity. Moreover, it showed that the aim of the various actors at various hierarchal scales of conservation is the same, to conserve the cattle breed. Yet, the underlying reasons for the conservation as well as the means for conservations are relatively different. Currently at the local level, the values of the cattle were more related to everyday livelihood strategies of single households, whereas the representatives of the republic, with the newspapers, highlighted the importance of the cattle for developing cattle production in the republic and the national identity. The diversity of reasons constitutes a challenge for developing collaboration between the various actors. On the other hand, the networking of scales and actors will develop with increasing globalization and new spaces for conservation will emerge. Our research project also constitutes a kind of space for conservation. By using a multidisciplinary approach it has been possible to increase awareness of the Yakutian Cattle and this will shape future conservation work.

[6] The aim of the reform is to standardize the local governance system in the Russian Federation, to make the distribution of responsibilities and assets transparent and to promote local decision making and democracy. The law was enacted in 2003, but its implementation has been challenging, mainly due to lack of human and financial resources.

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Recent Publication

Autochthonous farm animal breeds of Greece

Greek Focal Point for the Management of Animal Genetic Resources
Published in 2011, 44 pp.
Available in Greek and English (http://www.rfp-europe.org/fileadmin/SITE_ERFP/country_reports/Greece/Greek_FAbreeds_en.pdf)

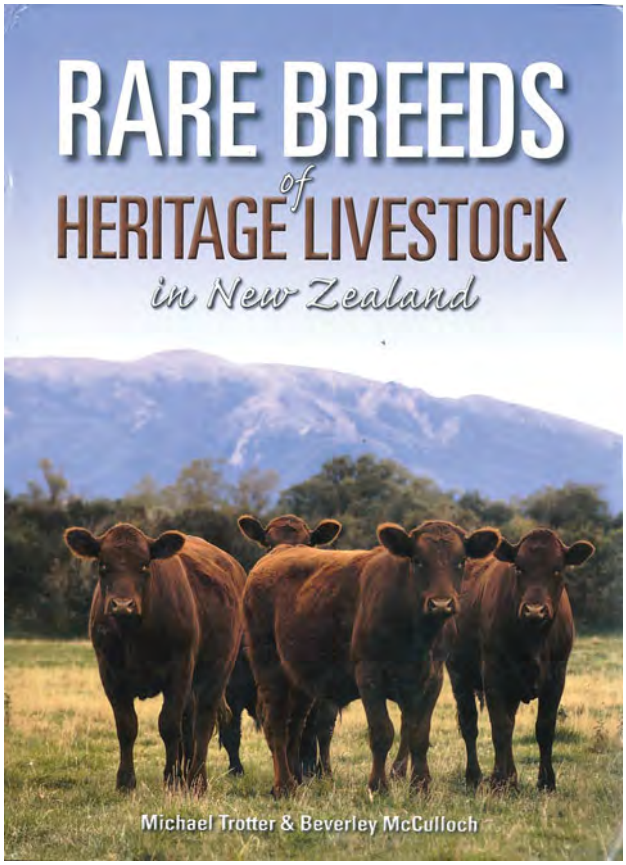
doi:10.1017/S2078633611000488

This publication, prepared for the occasion of the 7th International Exhibition for Livestock & Poultry – Zootechnia 2011, held in Thessaloniki, presents summary information on Greek breeds of cattle, buffalo, sheep, goat, pig, horse and donkey. For each breed, information is provided on their origin, location within the country, number of breeding females and risk status, along with short descriptions of the breeds and the conservation and breeding activities that are being implemented. Each breed description is illustrated with a colour photograph. The aim is to raise the awareness of the public about the importance of the livestock diversity of Greece. Data are drawn from the Greek EFABIS (European Farm Animal Biodiversity Information System) (http://www.efabis-greece.gr/).

Recent Publication

Rare breeds of heritage livestock in New Zealand
Edited by Michael Trotter and Beverley McCulloch.
David Bateman, published in 2010, 151 pp.
ISBN: 978-1-86953-774-6.

doi:10.1017/S207863611000049X



Originally, New Zealand had no livestock breeds of its own but when it was rediscovered in the 18th century, explorers and others started to introduce and/develop them. Initially livestock were introduced from Australia but later they came from Europe, mainly Britain. New Zealand at present has specific breeds of its own. The book deals with historical livestock breeds that were brought into or developed in New Zealand before 1950 and became rare and so reduced in numbers that their future is endangered. The book categorizes animal breeds into those of feral origin, and standard. It defines those of feral origin as the domestic animals that escaped or were set free and form breeding groups, living and reproducing themselves successfully in a wild situation. While standard breeds are 'the named breeds that are recognized by a formal registration system and are recorded – along with their pedigree or ancestry- in some sort of stud book'. Rare breeds of heritage discussed as feral are two goat, 12 sheep, one cattle, two pig, one horse, one donkey and one rabbit. While those considered as standard breeds are six sheep, five cattle, five pig and two horse. An overview was given for poultry breeds without providing further details. The book provides high quality photos of these breeds.

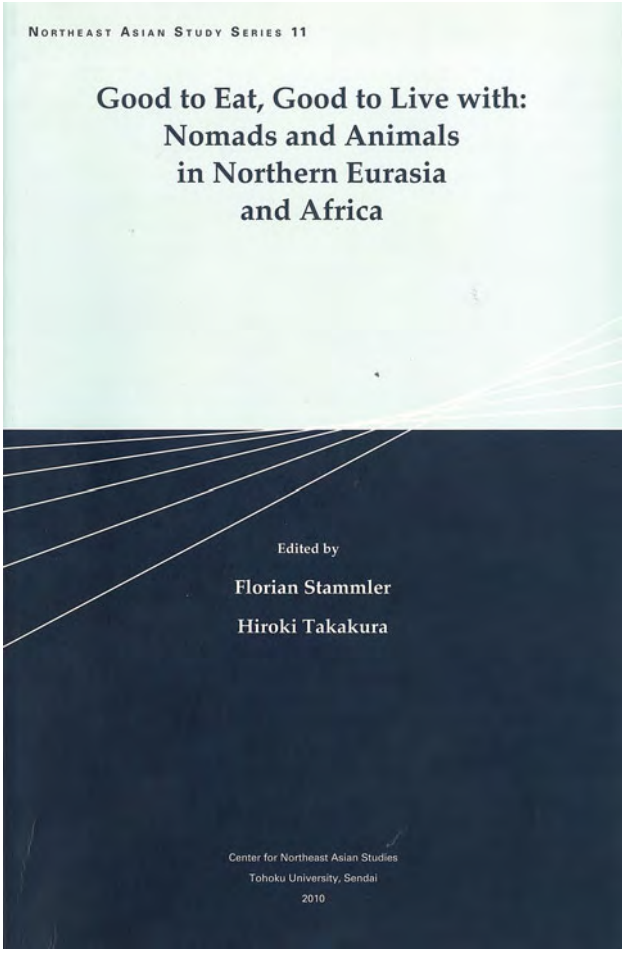
Animal Genetic Resources, 2011, 49, 109.

Recent Publication

Good to eat, good to live with: nomads and animals in northern Eurasia and Africa Northeast Asian Study Series 11

Edited by F. Stammler and H. Takakura
Center for North east Asian Studies, Tohoku University, Sendai
Published in 2010, 243 pp.
ISBN: 978-4-901449-67-0

doi:10.1017/S2078633611000506



This publication considers the social significance of animals in pastoral societies. Social significance is here defined as "a process of conversation in which animals give meaning to groups of people and individual humans through particular characteristics and practices based on these animals". The book comprises a series of papers that explore these questions in twelve pastoral societies on three continents. In addition to this "anthropocentric" viewpoint, some attention is also given to the significance of human decisions in maintaining particular genetically unique types of animals. The papers are divided into four clusters; the significance of the conceptual distinction between wild and domesticated animals; the importance of the socio-cultural factors for the subsistence dimension of human-animal relations in pastoralism; animal symbolism in its gendered, religious and political dimensions; and the global significance of local animal species for humanity. The latter of these clusters includes a chapter on the origin and diversity of Yakutian cattle as revealed by DNA-marker analysis and another on the links between biodiversity and "sociodiversity" using the example of a post-Soviet Siberian village. The book focuses largely on the northern parts of Eurasia, but also includes chapters on the Samburu pastoralists of northern Kenya and the Mbororo of Cameroon.

Recent Publication

Characterization and conservation of indigenous sheep genetic resources: a practical framework for developing countries

Solomon Gizaw, H. Komen, O. Hannotte, J.A.M. van Arendonk, S. Kemp, Aynalem Haile, O. Mwai and Tadelle Dessie

ILRI Research Report 27
International Livestock Research Institute.
Published in 2011, 37 pp.
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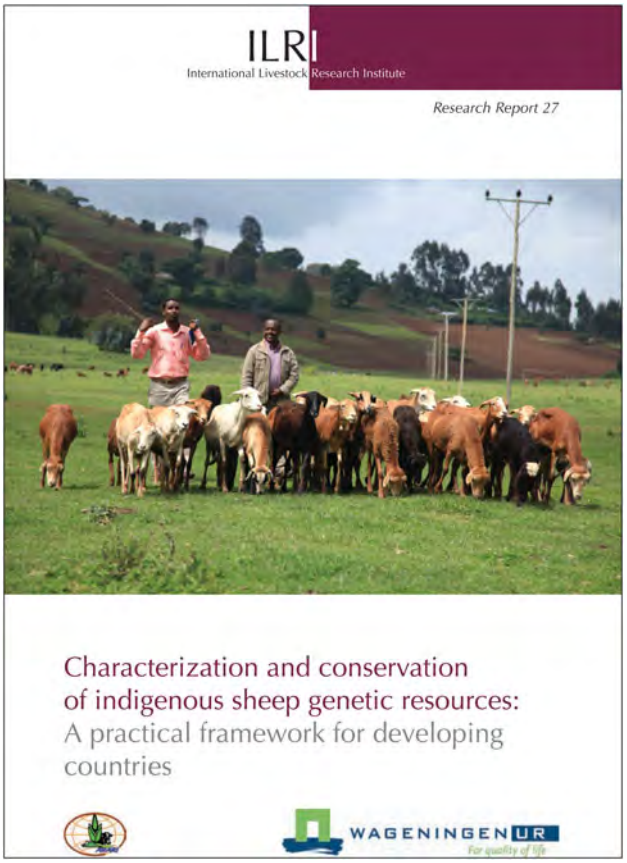
Available at http://mahider.ilri.org/bitstream/handle/10568/5371/9291462624__content.pdf?sequence=5

doi:10.1017/S2078633611000518



This publication presents a short introduction to characterization and conservation tools within the context of their practical application in developing countries. It draws on the results of a study on the characterization and conservation of sheep genetic resources in Ethiopia. An overview of approaches to characterization is followed by a discussion of practical considerations in planning and implementation, sampling strategies, the measurement of physical and performance characteristics, biogeographical mapping, production system description and molecular genetic characterization. A further subsection deals with approaches to classifying livestock populations. The section on conservation describes methods for setting conservation priorities as well as conservation methods. Attention is given to the roles of livestock-keeping communities and genetic improvement-based conservation. The conclusion is that characterization work in developing countries needs to focus on approaches that do not rely on time- and resource-intensive activities or on complicated tools. It is also argued that improvements to technical aspects of characterization and conservation need to be complemented by better coordination among the programmes and institutions involved.

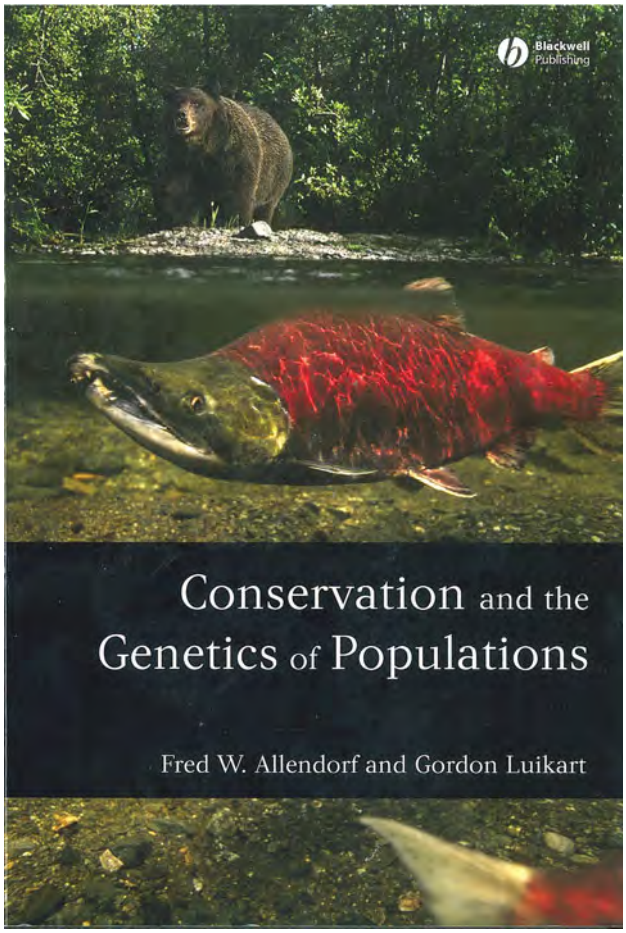
Recent Publication

Conservation and the genetics of populations

F.W. Allendorf and G. Luikart
Blackwell Publishing
Published in 2011, 642 pp.
ISBN: 978-1-4051-2145-3

doi:10.1017/S207863611000052X

This book, aimed at advanced undergraduate and graduate students and professional conservation biologists, provides an overview of the role of genetics in the conservation of (wild) species threatened with extinction. It examines genetic and phenotypic variation in natural populations, the principles and mechanisms of evolutionary change and the interpretation of genetic data from natural populations. Each chapter includes a "guest box" written by a leading author in the respective field and also contains a set of discussion questions and problems.

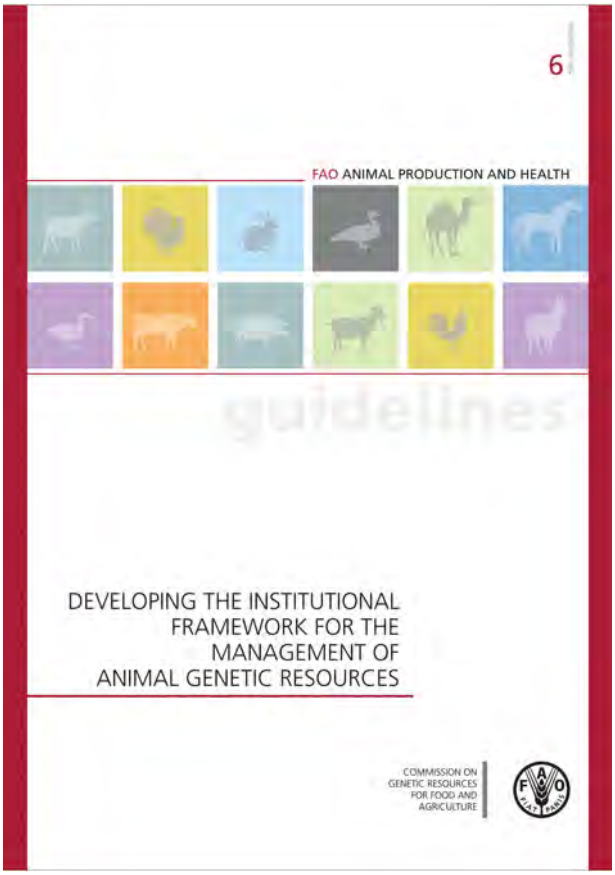


Recent Publication

Developing the institutional framework for the management of animal genetic resources

FAO Animal Production and Health Guidelines. No. 6
FAO
Published in 2011, 112 pp.
ISBN: 978-92-5-106972-1
Available at: http://www.fao.org/docrep/014/ba0054e/ba0054e00.pdf (English version;
French and Spanish versions in preparation)

doi:10.1017/S2078633611000580



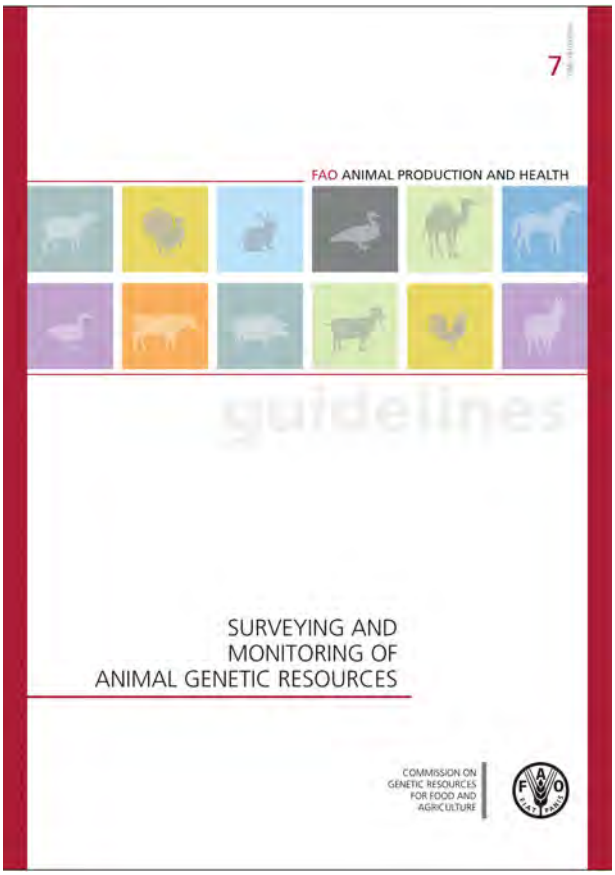
The Global Plan of Action for Animal Genetic Resources recognizes the important role of institutional frameworks in the sustainable management of animal genetic resources and the need for action to strengthen institutions both at national level and internationally. This new publication in FAO's Animal Production and Health Guidelines series provides both an overview of the existing global network for the management of animal genetic resources and advice on how national and regional institutions can be strengthened. Detailed guidance is provided on the role of National Coordinators for the Management of Animal Genetic Resources and the development and operation of National Focal Points for the Management of Animal Genetic Resources supported by National Advisory Committees, working groups and country stakeholder networks. Progress towards the establishment of a network of Regional Focal Points for Animal Genetic Resources is reviewed and advice provided for stakeholders wishing to establish and sustain focal points in their regions. The guidelines draw on lessons learned from many years of experience in the implementation of programmes and focal points for the management of animal genetic resources in many parts of the world, and include personal contributions from individuals who have been actively involved in this work.

Recent Publication

Surveying and monitoring of animal genetic resources

FAO Animal Production and Healt Guidelines. No. 7
FAO
Published in 2011, 144 pp.
ISBN: 978-92-5-106973-8
Available at http://www.fao.org/docrep/014/ba0055e/ba0055e00.htm (English version; French and Spanish versions in preparation)

doi:10.1017/S2078633611000592



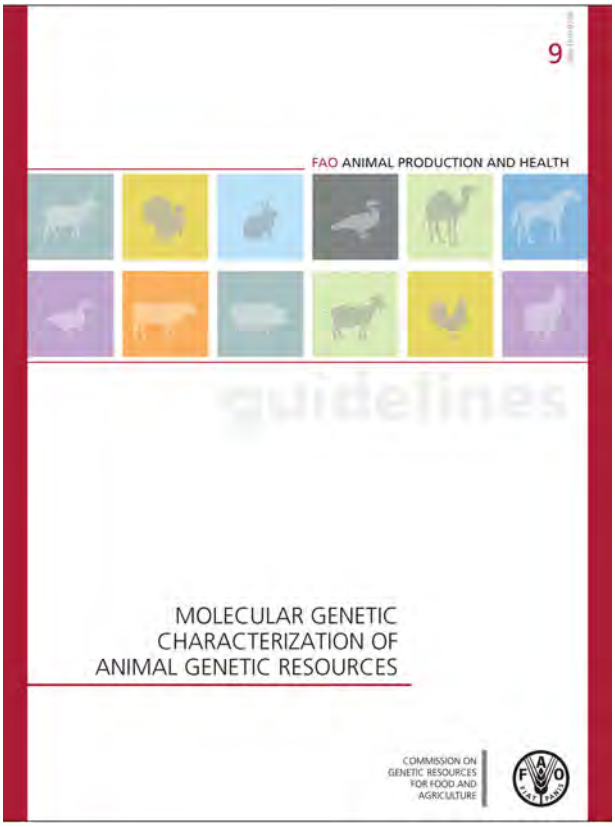
Knowledge of animal genetic resources is fundamental to their sustainable use, development and conservation. This publication provides advice on how to draw up a strategy for meeting national needs for data and information on animal genetic resources. It also offer practical advice on how to plan and implement an animal genetic resources survey – covering the whole process from planning the survey to disseminating the outputs and taking the first steps in translating results into action. A range of surveying tools are presented, and advice is offered on how they can be combined and integrated within an effective strategy that addresses both the task of acquiring a baseline of data on animal genetic resources and the subsequent task of monitoring changes over time.

Recent Publication

Molecular genetic characterization of animal genetic resources

FAO Animal Production and Health Guidelines. No. 9
FAO
Published in 2011, 85 pp.
ISBN: 978-92-5-107032-1
Available at http://www.fao.org/docrep/014/i2413e/i2413e00.pdf

doi:10.1017/S2078633611000609



This publication offers guidance to researchers planning a molecular characterization study. Practical advice is provided on planning, field and laboratory work, data management, data analysis, and on how the outputs of molecular studies can be used to support the sustainable use, development and conservation of animal genetic resources. The annexes include a glossary of technical terms, an example material transfer agreement for genetic material, a protocol for sampling blood for DNA, example questionnaires, a list of software for genetic analysis, and the International Society for Animal Genetics–FAO recommended list of microsatellite markers.

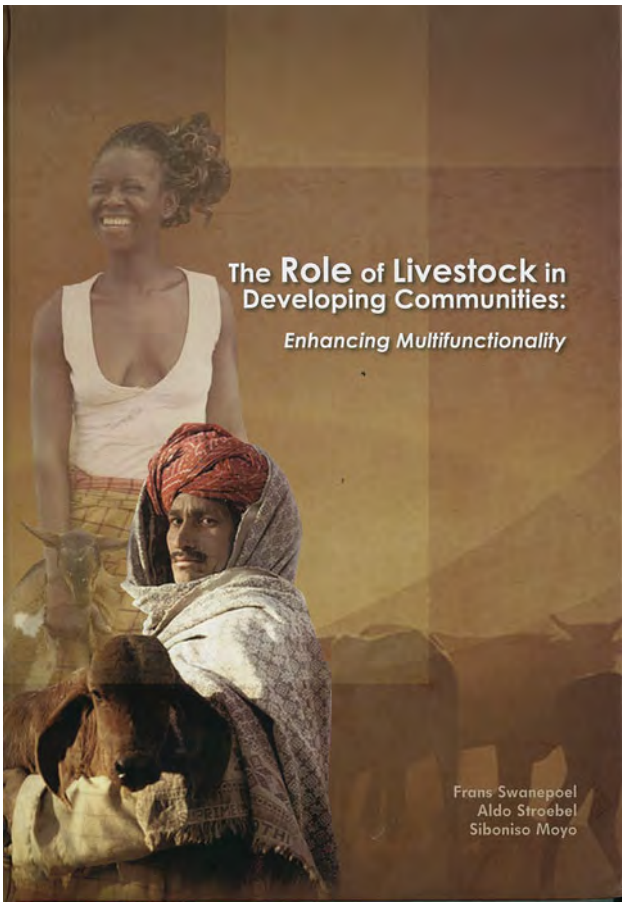
Animal Genetic Resources, 2011, 49, 115.

Recent Publication

The role of livestock in developing communities: enhancing multifunctionality

Edited by F. Swanepoel, A. Stroebel and S. Moyo
University of the Free State and CTA
Published in 2010, 213 pp.
ISBN: 978-0-86886-798-4

doi:10.1017/S2078633611000531



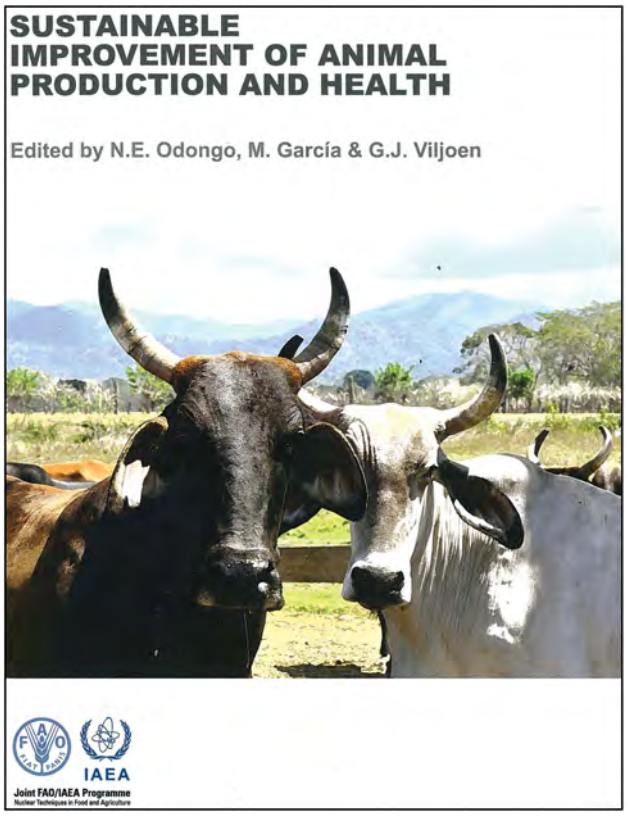
This publication is the product of a satellite symposium held as part of the 10th World Conference on Animal Production, held in Cape Town in November 2008, and jointly organized by the University of the Free State and the International Livestock Research Institute. It addresses the role of livestock in the global effort to alleviate poverty and improve human health. Following a brief overview of the various roles and functions that livestock play, the book's second chapter sets out a conceptual framework for the contribution of livestock to the livelihoods of developing communities, with the aim of helping to identify what works and what doesn't work in livestock development – and why. Six working principles are proposed: that livestock keeping forms part of rural people's (usually complex) livelihood strategies; that livestock are multifunctional; that the outcomes of livestock-related interventions are usually realized in the relatively long term and require substantial initial investment; that livestock production is affected by institutions, markets and policies as well as by technical constraints; that successful livestock programmes depend on wide stakeholder involvement; and that women play a substantial role in livestock keeping and their access to and benefits from livestock should be incorporated in development programmes. A series of more thematic chapters follows, dealing with promoting gender equality, environmental issues in livestock production, the role of animal products in human nutrition, the role of livestock in combating risk and vulnerability among poor households, sustainable intensification, and livestock value chains and innovation. The final chapter considers implications for innovative strategies for enhancing the contribution of livestock in the future.

Recent Publication

Sustainable improvement of animal health and production

N.E. Odongo, M. Garcia and G.J. Viljoen
FAO
Published in 2010, 393 pp.
ISBN: 978-92-5-106697-3

doi:10.1017/S2078633611000543



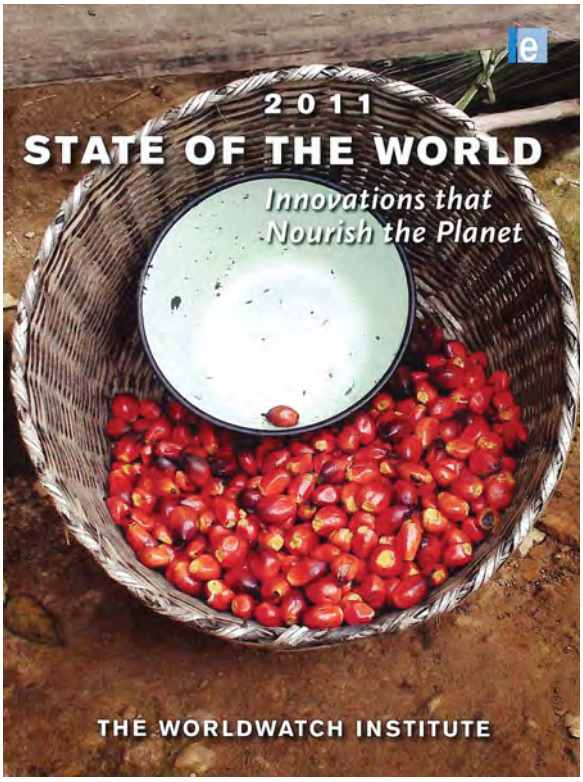
This publication is a product of a symposium organized by the Joint FAO/IAEA Division of Nuclear Techniques in Food and Agriculture in cooperation with the Animal Production and Health Division of FAO, which addressed the animal husbandry and public health issues that threaten global food security and safety. Papers from the five themed sessions of the symposium are preceded by context-setting papers on nuclear and related techniques in animal production and health and the implications for livestock production systems of declining resource availability. Sessions 1 and 2 – focusing, respectively, on "Interactions among nutrition, reproduction and genotype" and "The effects of nutrition, reproduction, genetics and environmental factors on animal productivity" – feature a wide range of papers including broad reviews of the implications of climate change for livestock production and diversity, the ethical foundations of science for livestock development and the management of livestock in degraded environments, as well numerous more specific studies on nutrition, breeding and genetic resources, reproductive technologies, service provision and animal husbandry. The papers from Session 3 – "Transboundary, emerging and zoonotic diseases" – include a further range of review and research papers covering, *inter alia*, diagnostic techniques, animal health information systems, climate change and disease, wildlife and emerging diseases, and coordination and decision making in disease control. Session 4 focused on "One Health", i.e. the move towards greater collaboration between the human and animal health sectors. A review paper on the topic is followed by papers on laboratory surveillance and on specific health problems. The final session "Achieving food safety and security in the 21st century" is also mostly devoted to animal health issues. The book also includes "Summary and conclusions" sections for each of the sessions.

Recent Publication

2011 state of the world – innovations that nourish the planet

A Woldwatch Institute report on progress towards a sustainable society
Earthscan
Published in 2011, 237 pp.
ISBN: 978-1-84971-352-8

doi:10.1017/S2078633611000555



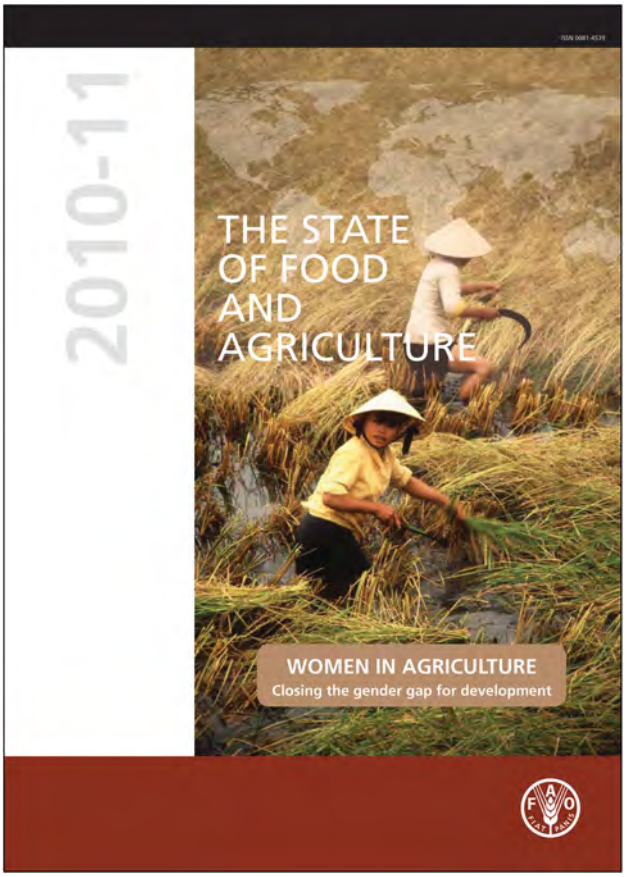
The 2011 edition of the World Watch Institutes flagship annual report focuses on agricultural innovations, specifically on the "treasure trove" of initiatives unearthed during visits to 25 countries of sub-Saharan Africa. The importance of such initiatives – emerging from farmers' groups, private voluntary organizations, universities and agribusinesses – is emphasized, particularly given the limitations of approaches based on more-of-the-same Green Revolution technologies in terms of their lack of effect on the livelihoods of many poor farmers and livestock keepers, their reliance on non-renewable resources and their destructive impacts on soils and biodiversity. Following an introductory chapter charting "a new path to eliminating hunger", the bulk of the book is made up of short chapters describing innovations in specific fields of agricultural development, each complemented by one or more case studies "from the field". The themes tackled include "Moving ecoagriculture into the mainstream". In this chapter, emphasis is given not only to the significance agroecological practices at the level of the farm or holding, but also to ecoagricultural landscapes – watershed conservation, maintenance of biodiversity, market development and so on. A chapter on the nutritional and economic potential of vegetables highlights the need for a "revolution of greens", i.e. for increases in grain production to be complemented by increases in the production of other foods needed to provide a balance diet. "Africa's soil fertility crisis and the coming famine" presents an alarming description of a "perfect storm" of factors threatening the continent's soils, and proposes solutions – focusing largely on the potential of green manure/cover crops. The chapter "Safeguarding local food biodiversity" focuses not so much on safeguarding for its own sake, or even for the sake of future options, but rather on examples in which diversity contributes to improving local livelihoods. The main examples discussed involve plants, marine molluscs and honey. However, the chapter includes a text box on threats to animal genetic resources in Kenya and a reference to Zulu sheep. A chapter on "Coping with climate change" includes subsections on the importance of properly evaluating climate adaptation measures, farmer-managed "re-greening" and the climate consequences of different diets. "Industrial" livestock production comes in for heavy criticism. Further chapters address urban agriculture, post-harvest losses, the management of water resources, foreign investment in African land and the knowledge and skills of women farmers. A chapter on "Improving food production from livestock" focuses on improvements to feeding strategies, animal health and responses to climate change. In the final chapter of the book "some of the world's leading thinkers, scientists, and advocates in agricultural development" offer a "roadmap for nourishing the planet", divided into subsections covering innovations in understanding complex systems, evaluating agricultural development projects, institutions, governance and policy reform.

Recent Publication

The State of Food and Agriculture 2010–11
Women in agriculture. Closing the gender gap for development

FAO
Published in 2011, 247 pp.
ISBN: 978-92-5-106768-0
Available at http://www.fao.org/docrep/013/i2050e/i2050e00.htm
(also in Arabic, Chinese, French, Russian and Spanish)

doi:10.1017/S2078633611000567



The latest edition of the FAO flagship publication *The State of Food and Agriculture* addresses the role of women in agriculture, highlighting in particular the gender gap that exist in terms of access to assets such as land, livestock, labour, education, extension and financial services, and technology, and the contribution that closing this gap would make to development. More specifically, various sections of report survey the roles and status of women in agriculture and rural areas in different parts of the document the constraints facing women in agriculture, survey the economic evidence on the productivity of female and male farmers and the gains that could be made from closing the gender gap in input use, advance specific policies and programmes that could close the gender gap in agriculture and rural employment. A subsection on "Women as livestock keepers" offers a short overview of the roles of women in livestock keeping and how their engagement in the livestock sector as livestock keepers or wage labourers may be affected by the spread of intensive commercial production systems. Another subsection focuses on the gender gap in livestock ownership in various parts of the world.

Animal Genetic Resources, 2011, 49, 119–121. © Food and Agriculture Organization of the United Nations, 2011
doi:10.1017/S2078633611000452

Instructions for contributors

Animal Genetic Resources is a trilingual journal, published three times per year online (http://journals.cambridge.org/AGR) and in print. Main papers are published in English, French or Spanish, with a summary in all three languages. The journal has been published since 1983, and all back issues are available at http://dad.fao.org/cgi-bin/EfabisWeb.cgi?sid=−1,refcat_50000044.

The journal encourages submissions from all over the world. Authors who are not fluent in any of the three accepted languages are encouraged to seek assistance in this regard before submitting their manuscripts.

Mission statement

The journal provides an international forum for the publication of papers related to the management of animal genetic resources for food and agriculture (AnGR). It covers the following areas: phenotypic and molecular characterization; surveying and monitoring; development (genetic improvement); sustainable use; conservation; capacity-building in livestock keeper and pastoralist communities; and policies and institutions.

The editors welcome all papers addressing the topics above. Papers related to breeds and technologies contributing to the sustainable management of the world's medium-to-low input production systems, which account for the largest area of land involved in livestock production and for a major part of production from livestock, are of a particular interest.

The journal supports the implementation of the Global Plan of Action for Animal Genetic Resources, the internationally agreed framework for the management of AnGR and the Convention on Biological Diversity.

Disclaimer

Views expressed in the papers published in Animal Genetic Resources represent the opinions of the author(s) and do not necessarily reflect the policies of FAO or the views of the editors or the institutions with which the authors are affiliated.

Peer review

Manuscripts submitted for publication in Animal Genetic Resources undergo full peer review by two referees. The suitability of manuscripts is judged by the reviewers and editors, and the editors' decision on a paper is final.

Categories of papers

Research papers – Findings of work related to the management of AnGR will be considered for publication in AGRI. Authors are encouraged to include relevant high-quality photographs in their manuscripts. If photographs illustrate animals, they should be shown in the primary production environment to which they are adapted.

Review papers – Unsolicited papers reviewing country-level, regional or global developments in one or more aspects of AnGR management will be considered for publication. These papers may include state-of-the-art reviews of specific fields in AnGR management.

Position papers – Invited papers on topical issues will be published when the editors consider there to be such a requirement.

Other published material – Readers are encouraged to send the following items by e-mail to AnGR-Journal@fao.org:

- book reviews or proposals
- conclusions and recommendations arising from relevant meetings, workshops and conferences
- announcements of training courses and major national, regional and international events

Originality and copyright

To be considered for publication in the journal, a manuscript must not have been published previously, nor be under review for publication elsewhere. (Previously published figures may be used sparingly in reviews, provided that permission has been obtained as appropriate.) Prior to publication, an authorization and copyright transfer agreement form must be signed and returned to the publishers by the lead or corresponding author of a manuscript (corresponding authors sign on behalf of any co-authors). The form will be sent to the lead or corresponding author together with the proof of the paper for publication.

Authorship

Papers with multiple authors are reviewed with the assumption that all authors have contributed materially to the research reported, have approved the submitted manuscript, and concur with its submission. A contribution includes the conception and design of the project, the performance of experiments and/or the analysis and interpretation of data. Authors should have made a substantial intellectual contribution to the drafting or critical revision of the manuscript.

Manuscript submission

All manuscripts must be submitted online at http://journals.cambridge.org/AGR. No page charges are required from the author.

Receipt of your manuscript will be acknowledged, a manuscript reference number assigned and the manuscript will be sent out for review. You should quote your manuscript reference number in all subsequent correspondence.

The following instructions must be followed carefully (see *Manuscript preparation and style* for further details):

- Manuscripts may be submitted in English, French or Spanish. If your manuscript is written in French or Spanish, it should include a summary and keywords in that language as well as in English. All published articles will feature a summary in English, French and Spanish. It would be appreciated if, wherever possible, authors could supply a summary in all three languages, as this reduces the need for translating services and therefore expedites processing of the manuscript.
- The preferred file format for submission is Microsoft Word. Word Perfect or other word-processor files are not acceptable. Tables should be included within the same file but at the end of the document. Placeholders should be used within the text to indicate their positioning.
- Figures must be submitted as separate files, and at to-be-published resolution (see Manuscript preparation and style for further details).
- A cover letter should be provided as a separate file. The letter should indicate the category under which the manuscript is submitted (see Appendix 1) and provide the details of the corresponding author (telephone number, fax number and e-mail address).
- Filenames should indicate the name of the first author of the paper, either in full or abbreviated.
- Printed copies of the manuscript, tables and figures are not required and should not be sent.

Please note that correspondence regarding submitted and revised manuscripts will take place with the corresponding author only.

Manuscript preparation and style

The manuscript should be formatted with line spacing set to "double". Pages should be numbered sequentially beginning with the title page. Margins should be at least 2.5 cm on all sides. The font should be set to Arial.

Authors and affiliations – Names and affiliations of authors should be presented as follows:

E.C. Quispe[1], T.C. Rodríguez[2], L.R. Iñiguez[3] and J.P. Mueller[4]

[1]Universidad Nacional de Huancavelica, Huancavelica, Perú; [2]Universidad Mayor de San Andrés, La Paz, Bolivia; [3]Cochabamba, Bolivia; [4]Instituto Nacional de Tecnología Agropecuaria, Bariloche, Argentina

Correspondence to: E.C. Quispe, Universidad Nacional de Huancavelica, Huancavelica, Perú. E-mail: edgarquispe62@yahoo.com

A ***Running Head*** of up to 50 characters should be provided on the title page.

The ***Summary*** should be unstructured (i.e., no sub-headings) but must provide the reader with a self-contained summary of the paper. It should include a brief introduction to the paper, the method, the key findings and the conclusions. The summary should be no longer than 210 words in English and 250 words in French and Spanish. A list of three to five keywords or terms for indexing should follow the summary and be separated by commas. The summary and keywords should be provided in the same language as the manuscript as well as in English.

The ***Body of the manuscript*** should begin on page 3 and a new page should be used for the References. The lines of text must be numbered and the manuscript structured with consecutively numbered headers and sub-headers (e.g. 1., 1.1, 1.1.1 etc). However, it is important to *avoid cross-referencing using these numbers*, as the editorial office will remove numbering and apply heading styles in the final version.

Research papers should additionally include the following headers: ***Materials and Methods***; ***Results***; ***Discussion***; ***Conclusions***.

The ***Maximum length*** of the body of the manuscript should not exceed 10 journal pages (approx. 8 500 words). Short communications should not exceed 1 journal page (approx. 750 words or, when an image is included, 550 words).

Tables should be numbered consecutively as they are cited in the text (Table 1, 2 etc.). Each table should be on a separate page (at the end of the document) with the number and heading above and any notes below the table.

Figures should be numbered consecutively as they are cited in the text (Figure 1, 2, etc). Use italic letters for parts a, b, c, etc. Legends must be provided for each figure. If applicable, figures should be supplied as either TIFF or EPS files, preferably at the approximate size in which they are to be reproduced. Line artwork should be supplied in black and white mode at a resolution of 1 200 dpi; combination artwork (line/tone) at a resolution of 800 dpi; black and white halftone artwork should be saved in "grayscale" mode at a resolution of 300 dpi; colour halftone artwork should be saved in CMYK mode at a resolution of 400 dpi. All necessary permissions must be obtained.

Abbreviations and SI units – The use of abbreviations, except those that are widely used, is strongly discouraged. They should be used only if they improve comprehension of the manuscript. Acronyms should be spelled out at first mention. Metric system (SI) units should be used.

Acknowledgements

In this section authors should acknowledge any support from granting agencies and other sources for the work reported in their paper. The contribution of individuals who assisted with the research but are not included as authors of the paper may also be acknowledged in this section.

The Acknowledgements should be placed after the main body of the text before the references. If there are no Acknowledgements, the title should be inserted followed by "None".

Statement of interest

A conflict of interest exists when an author has interests that might inappropriately influence his or her judgement, even if that judgement is not influenced. Because of this, authors must disclose potentially conflicting interests so that others can make judgements about such effects. At the time of manuscript submission, authors should disclose any financial arrangements or connections they may have that are pertinent to the submitted manuscript and that may be perceived as potentially biasing their paper. Non-financial interests that could be

relevant in this context should also be disclosed. If no relevant interests exist, this should be stated. This requirement applies to all the authors of a paper and to all categories of papers.

References

Every reference cited in the text should be included in the reference list and every entry in the reference list should have been mentioned in the text at least once. References should be ordered first alphabetically by the first author's surname, and then by year.

Examples:

1 *Reference in a periodical*:
Köhler-Rollefson, I. 1992. The camel breeds of India in social and historical perspective. *Animal Genetic Resources Information* 10: 53–64.

2 *When there is more than one author*:
Matos, C.A.P., Thomas, D.L., Gianola, D., Tempelman, R.J. & Young, L.D. 1997. Genetic analysis of discrete reproductive traits in sheep using linear and non-linear models: 1. Estimation of genetic parameters, *Journal of Animal Science* 75: 76–87.

3 *For a book or an* ad hoc *publication, e.g., reports, theses*:
FAO, 2007. Global Plan of Action for Animal Genetic Resources and the Interlaken Declaration. Food and Agriculture Organization of the United Nations, Rome, Italy (available at http://www.fao.org/docrep/010/a1404e/a1404e00.htm).
van der Werf, J., Graser, H-U., Frankham, R. & Gondro, C. (eds.) 2009. Adaptation and fitness in animal populations. evolutionary and breeding perspectives on genetic resources management. Springer.

4 *For an article in the proceedings of a meeting*:
Abad, M., Arrigo, J., Gibbons, A., Lanari, M.R., Morris, G. & Taddeo, H. 2002. Breeding scheme for Angora goat production in North Patagonia. Proceedings 7th World Congress on Genetics Applied to Livestock Production, 19-23 August 2002, Montpellier, France, 12–14.

5 *Information hosted on a web site*:
FAO. 2010. Domestic Animal Diversity Information System, http://www.fao.org/dad-is/, Food and Agriculture Organization of the United Nations, Rome, Italy.

For a work that has been accepted for publication but not yet published, "In press" should be written in place of the year of publication. Do not insert an expected year of publication.

Supplementary online material

The online platform gives authors the opportunity to include data that would be impossible or impractical to include in the printed version. Authors may include tables and figures as well as data such as videos, 3-D structures/images, extensive datasets and any other supplementary material not suitable for print duplication. All supplementary material must be submitted with the original manuscript. Supplementary data should be referred to in the text with the prefix "S" (e.g. Supplementary Table S1, Supplementary Figure S1). Supplementary files will not be copyedited but will be published as supplied. The electronic publication of this material needs to be approved by the editors. The manuscript must be able to stand alone without the supplementary material (for the benefit of readers with access to the hard copy only).

Review process

Manuscripts submitted to the journal will be reviewed by two external reviewers and evaluated by one of the editors. If the editors deem that a paper is not relevant for this journal or is unlikely to be reviewed favourably, it may be returned to the author after initial review by the editors. This rapid rejection process enables the author to submit the work promptly for publication elsewhere. Manuscripts may also be rejected by the editors if they do not comply with the recommendations for preparation of manuscripts. Every effort will be made to provide authors with a review decision within six weeks of receipt of the manuscript. If the editors request revisions to a manuscript before publication, a maximum of one month shall be allowed for such revisions to be implemented.

Proofs

The publisher reserves the right to copyedit manuscripts to ensure that grammar and spelling are consistent with the style of the journal. The corresponding author will receive page proofs for final proofreading. These should be checked and returned within two days of receipt. The publisher reserves the right to charge authors for excessive correction of non-typographical errors.

Animal Genetic Resources, 2011, 49, 123–125. © Food and Agriculture Organization of the United Nations, 2011
doi:10.1017/S2078633611000464

Instructions pour les auteurs

Animal Genetic Resources/Resources génétiques animales/Recursos genéticos animales est un journal trilingue, publié trois fois par an en ligne (http://journals.cambridge.org/AGR) et en version imprimée. Les articles principaux sont publiés en anglais, français ou espagnol avec un résumé dans les trois langues. Le journal est publié depuis 1983 et tous les anciens numéros sont disponibles à l'adresse électronique http://dad.fao.org/cgi-bin/EfabisWeb.cgi?sid=-1,refcat_50000044.

On encourage la présentation d'articles provenant du monde entier à publier dans le journal. Les auteurs qui ne parlent aucune des trois langues admises sont encouragés à chercher de l'aide à cet égard avant de présenter leurs manuscrits.

Déclaration de mission

Le journal fait office de forum international pour la publication d'articles concernant la gestion des ressources zoogénétiques pour l'alimentation et l'agriculture. Il aborde en particulier les thèmes suivants: la caractérisation phénotypique et moléculaire; les enquêtes et le suivi; la mise en valeur (amélioration génétique); l'utilisation durable; la conservation; le renforcement des capacités au sein des communautés d'éleveurs et de pasteurs; et les politiques et les institutions.

Les éditeurs accueillent favorablement tous les articles abordant les thèmes indiqués ci-dessus. Un intérêt particulier sera attribué aux articles concernant les races et les technologies en faveur de la gestion durable des systèmes de production extensive ou semi-intensive dans le monde, qui représentent la plus grande partie des terres consacrées à l'élevage et une partie considérable de la production provenant de l'élevage.

Le journal soutient la mise en œuvre du Plan d'action mondial pour les ressources zoogénétiques, le cadre internationalement convenu en matière de gestion des ressources animales et la Convention sur la diversité biologique.

Déni de responsabilité

Les opinions exprimées dans les articles publiés dans Animal Genetic Resources/Resources génétiques animales/Recursos genéticos animales sont celles du/des auteur(s) et ne reflètent pas nécessairement les politiques de la FAO ou les opinions des éditeurs ou des institutions pour lesquelles ils travaillent.

Révision par les pairs

Deux experts s'occuperont de la révision complète des manuscrits présentés pour la publication dans Animal Genetic Resources/Resources génétiques animales/Recursos genéticos animales. L'opportunité ou non de publier un manuscrit sera jugée par les réviseurs et par les éditeurs, et la décision finale sur l'article appartient aux éditeurs.

Types d'articles

Articles de recherche – Seront prises en considération pour leur publication sur AGR les études sur la gestion des ressources animales. On encourage les auteurs à envoyer des photographies de haute qualité avec les manuscrits. S'il s'agit de photographies d'animaux, il faudra montrer les races en question dans leur milieu naturel de production.

Révisions – Occasionnellement, des articles contenant une révision aux niveaux national, régional ou mondial des développements d'un ou de plusieurs aspects se rapportant à la gestion des ressources animales seront pris en considération. Ces articles pourront inclure les mises à jour des différents domaines de la gestion des ressources animales.

Articles spécifiques – Ponctuellement, des articles sur des thèmes spécifiques pourront être demandés pour la publication lorsque les éditeurs le jugeront nécessaire.

Autre matériel pour publication – On encourage les lecteurs à envoyer par courrier électronique à l'adresse AnGR-Journal@fao.org:

- la révision ou la proposition de livres
- les conclusions et les recommandations résultant de réunions, d'ateliers et de conférences importants
- les informations sur des cours de formation et sur les principaux événements régionaux, nationaux et internationaux.

Originalité et droits d'auteur

Pour que le manuscrit soit considéré pour la publication dans le journal, il faut qu'il n'ait pas été publié auparavant, ni qu'il soit en cours de révision pour la publication dans d'autres ouvrages. (Les chiffres publiés auparavant peuvent s'utiliser avec parcimonie dans les révisions, à condition d'en avoir obtenu l'autorisation.) Avant la publication, il faut que l'auteur principal du manuscrit signe et renvoie aux éditeurs le formulaire d'autorisation et d'accord de transfert des droits d'auteur (les auteurs principaux signent au nom de tous les co-auteurs). Le formulaire sera envoyé à l'auteur principal avec l'épreuve de l'article pour la publication.

Paternité

Les articles écrits par plusieurs auteurs sont révisés en présumant que tous les auteurs ont matériellement participé à la recherche signalée, ont approuvé le manuscrit présenté et approuvent sa présentation. Leur contribution comprend la conception et la création du projet, la performance d'expériences et/ou l'analyse et l'interprétation des données. Les auteurs devront avoir apporté une contribution intellectuelle considérable à la rédaction et à la révision critique du manuscrit.

Présentation du manuscrit

Tous les manuscrits seront présentés en ligne à l'adresse électronique http://journals.cambridge.org/AGR. Aucune charge par page ne sera requise de l'auteur.

On accusera réception du manuscrit, on attribuera un numéro de référence et le manuscrit sera envoyé pour révision. Vous devrez toujours indiquer le numéro de référence de votre manuscrit dans toute correspondance ultérieure.

Il faut suivre avec attention les instructions ci-après (pour de plus amples détails, voir *Préparation et style du manuscrit).*

- Les manuscrits se présenteront en anglais, français ou espagnol. Si votre manuscrit est en français ou en espagnol, il faudra ajouter un résumé et les mots clés dans cette langue ainsi qu'en anglais. On ajoutera à tous les articles publiés un résumé en anglais, français et espagnol. On appréciera si, dans la mesure du possible, les auteurs fournissent un résumé dans les trois langues, car les services de traduction seraient ainsi réduits et le traitement du manuscrit serait par conséquent plus rapide.
- Le format de fichier préféré pour la présentation est Microsoft Word. Word Perfect ou d'autres fichiers de traitement de texte ne sont pas acceptés. Les tableaux seront inclus au même fichier, mais à la fin du document. Les paramètres fictifs seront utilisés dans le texte pour indiquer leur positionnement.
- Les figures se présenteront en tant que fichiers séparés et en résolution publiable (pour de plus amples détails voir *Préparation et style du manuscrit*).
- Une lettre d'envoi sera envoyée dans un fichier séparé. La lettre signalera la catégorie d'appartenance du manuscrit (voir annexe 1) et fournira des informations sur l'auteur principal (numéro de téléphone, de télécopieur et adresse électronique).
- Les fichiers indiqueront le nom de l'auteur principal de l'article, soit en entier soit abrégé.
- Les copies imprimées du manuscrit, des tableaux et des figures ne sont pas requises et ne devront pas être envoyées.

Veuillez noter que la correspondance relative aux manuscrits présentés et révisés se fera uniquement avec l'auteur principal.

Préparation et style du manuscrit

Les manuscrits se présenteront à «double» interligne. Toutes les pages seront numérotées à commencer de la page du titre. Les marges seront d'au moins 2,5 cm pour tous les côtés. La police de caractère sera Arial.

Auteurs et institutions pour lesquelles ils travaillent – Les noms des auteurs et les institutions pour lesquelles ils travaillent se présenteront comme indiqué ci-après:

E.C. Quispe[1], T.C. Rodríguez[2], L.R. Iñiguez[3] et J.P. Mueller[4]

[1]Universidad Nacional de Huancavelica, Huancavelica, Perú; [2]Universidad Mayor de San Andrés, La Paz, Bolivia; [3]Cochabamba, Bolivia; [4]Instituto Nacional de Tecnología Agropecuaria, Bariloche, Argentina

Correspondance à envoyer à: E.C. Quispe, Universidad Nacional de Huancavelica, Huancavelica, Perú. Adresse électronique: edgarquispe62@yahoo.com

Sur la première page du manuscrit, on indiquera le ***titre de l'article*** qui ne devra pas dépasser les 50 caractères.

Le ***résumé*** ne sera pas structuré (c'est-à-dire, sans sous-titres), mais devra fournir au lecteur une brève description de l'article. Il inclura une introduction succincte à l'article, la méthode utilisée, les résultats principaux et les conclusions. Le résumé ne dépassera pas les 210 mots en anglais et les 250 mots en français et en espagnol. Une liste de mots clés ou de termes (entre trois et cinq) pour le sommaire suivra le résumé et les mots-clés seront séparés par des virgules. Le résumé et les mots-clés se présenteront dans la même langue du manuscrit ainsi qu'en anglais.

Le ***corps du manuscrit*** commencera à la page 3 et une nouvelle page sera utilisée pour les références. Les lignes du texte seront numérotées, le manuscrit sera structuré et tous les titres et les sous-titres seront numérotés (par exemple, 1, 1.1, 1.1.1, etc.). Il est toutefois important *d'éviter les références croisées avec ces numéros* car le bureau d'édition enlèvera la numérotation et appliquera des styles de titre dans la version finale.

Les articles de recherche devront en outre inclure les titres suivants: ***Matériels et méthodes; Résultats; Débat; Conclusions.***

La ***longueur maximale*** du corps du manuscrit ne dépassera pas les 10 pages du journal (environ 8 500 mots). Les communications brèves ne dépasseront pas 1 page (environ 750 mots ou, s'il y a également une image, 550 mots).

Les ***tableaux*** seront tous numérotés en suivant l'ordre d'apparition dans le texte (tableau 1, 2 etc.). Chaque tableau sera sur une page séparée (à la fin du document) avec le numéro et le titre au-dessus du tableau et d'éventuelles notes au-dessous.

Les ***figures*** seront toutes numérotées en suivant l'ordre d'apparition dans le texte (figure 1, 2 etc.). Il faudra écrire les lettres des parties a, b, c, etc. en italique et prévoir des légendes pour chaque figure. Les figures se présenteront, si possible, dans un fichier TIFF ou EPS, de préférence dans la taille approximative à utiliser pour la reproduction. Les illustrations graphiques seront fournies en noir et blanc avec une résolution de 1 200 ppp; les artwork combinaisons (ligne/ton) avec un résolution de 800 ppp; les illustrations en demi-ton noir et blanc seront sauvegardées en mode «niveau de gris» avec une résolution de 300 ppp; les illustrations en demi-teinte de couleurs seront enregistrées en mode CMJN avec une résolution de 400 ppp. Il faudra obtenir toutes les autorisations nécessaires.

Abréviations et unités SI – L'utilisation des abréviations, à part celles qui sont largement employées, est vivement déconseillée. Elles ne seront utilisées que si elles améliorent la compréhension du manuscrit. Les sigles s'écriront en entier la première fois qu'elles sont employées. Il faudra utiliser les unités du système métrique (SI).

Remerciements

Dans cette section, les auteurs remercieront pour tout appui reçu des institutions et d'autres sources de soutien pour le travail inscrit dans leur article. On peut ajouter également dans cette section la contribution d'autres particuliers ayant aidé dans le travail de recherche, mais n'étant pas inclus en tant qu'auteurs.

Les remerciements seront placés après le corps principal du texte avant les références. En cas d'absence de remerciements, le titre sera toutefois écrit et suivi par l'indication «aucun remerciement».

Déclaration d'intérêts

On est en présence d'un conflit d'intérêts lorsqu'un auteur a des intérêts qui pourraient influencer de façon inappropriée son jugement, même si ce jugement n'est pas en fait influencé. Pour cette raison, les auteurs doivent révéler les conflits d'intérêts potentiels pour que d'autres puissent juger de ces effets. Au moment de la présentation du manuscrit, les auteurs révéleront tout arrangement ou rapport financier pertinent avec le manuscrit présenté et qui pourrait être perçu comme pouvant porter un préjudice potentiel à l'article. Les auteurs révéleront également les intérêts non financiers qui pourraient être pertinents dans ce contexte. Il faudra également déclarer l'absence d'intérêts pertinents. Cette obligation s'applique à tous les auteurs d'un article et à toutes les catégories d'articles.

Références

Toute référence présente dans le texte devra apparaître sur la liste des références, et chaque entrée de la liste aura été citée au moins une fois dans le texte. Les références iront en ordre alphabétique du nom de l'auteur, suivi de l'année.

Exemples:

1 *Référence sur une revue:*
Köhler-Rollefson, I. 1992. The camel breeds of India in social and historical perspective. *Animal Genetic Resources Information* 10: 53–64.

2 *Lorsqu'il s'agit de plus d'un auteur*:
Matos, C.A.P., Thomas, D.L., Gianola, D., Tempelman, R. J. et Young, L.D. 1997. Genetic analysis of discrete reproductive traits in sheep using linear and non-linear models: 1. Estimation of genetic parameters, *Journal of Animal Science* 75: 76–87.

3 *Dans le cas d'un livre ou d'une publication ad hoc, par exemple, un rapport, une thèse:*
FAO, 2007. Plan mondial d'action pour les ressources zoogénétiques et la Déclaration d'Interlaken. Organisation des Nations Unies pour l'alimentation et l'agriculture, Rome, Italie (disponible à l'adresse électronique http://www.fao.org/docrep/010/a1404f/a1404f00.htm).
van der Werf, J., Graser, H-U., Frankham, R. et Gondro, C. (éds.) 2009. Adaptation and fitness in animal populations. Evolutionary and breeding perspectives on genetic resources management. Springer.

4 *S'il s'agit d'un acte d'une réunion*:
Abad, M., Arrigo, J., Gibbons, A., Lanari, M.R., Morris, G. et Taddeo, H. 2002. Breeding scheme for Angora goat production in North Patagonia. Actes du Septième congrès mondial sur l'application de la génétique à l'élevage, 19-23 août 2002, Montpellier, France, 12–14.

5 *Dans le cas d'informations hébergées sur un site Web:*
FAO. 2010. Domestic Animal Diversity Information System, http://www.fao.org/dad-is/, Organisation des Nations Unies pour l'alimentation et l'agriculture, Rome, Italie.

Dans le cas d'un travail ayant été accepté pour la publication, mais n'ayant pas encore été publié, on écrira «sous presse» à la place de l'année de la publication. Il ne faudra pas écrire l'année prévue de la publication.

Documentation supplémentaire en ligne

La plate-forme en ligne donne la possibilité aux auteurs d'ajouter des données qui seraient autrement impossibles ou pas pratiques à inclure à la version imprimée. Les auteurs pourront inclure des tableaux et des figures ainsi que des données comme des vidéos, des images/structures en trois dimensions, des ensembles de données très détaillées et d'autres matériels supplémentaires ne convenant pas à la reproduction sur papier. Tout le matériel supplémentaire se présentera avec le manuscrit original. Les données supplémentaires seront indiquées dans le texte par le préfixe «S» (par exemple, tableau supplémentaire S1, figure supplémentaire S1). Les fichiers supplémentaires ne seront pas révisés et seront publiés tels que reçus. Les éditeurs devront approuver la publication électronique de ce matériel. Le manuscrit devra être autonome et se suffire à lui-même, sans le matériel supplémentaire (dans l'intérêt des lecteurs ayant uniquement accès à la copie papier).

Processus d'examen

Les manuscrits présentés au journal seront examinés par deux réviseurs externes et évalués par un des éditeurs. Si les éditeurs considèrent que l'article n'est pas pertinent avec ce journal ou que l'examen ne sera pas favorable, l'article pourra être renvoyé à l'auteur après l'examen initial des éditeurs. Ce processus de refus rapide permet à l'auteur de présenter immédiatement son travail ailleurs pour publication. Les manuscrits seront également refusés par les éditeurs s'ils ne sont pas conformes aux recommandations prévues pour leur préparation. Tous les efforts seront faits pour communiquer aux auteurs la décision de l'examen dans un délai de six semaines après la réception du manuscrit. Si les éditeurs demandent des révisions au manuscrit avant sa publication, on accordera un délai maximum d'un mois pour ces révisions.

Epreuves

L'éditeur se réserve le droit de réviser les manuscrits pour veiller à ce que la grammaire et l'orthographe soient cohérentes avec le style du journal. L'auteur principal recevra les épreuves en page pour la correction. Ces épreuves seront contrôlées et renvoyées dans un délai de deux jours après la réception. L'éditeur se réserve le droit de charger les auteurs en cas de correction excessive d'erreurs non typographiques.

Animal Genetic Resources, 2011, 49, 127–129. © Food and Agriculture Organization of the United Nations, 2011
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Instrucciones para los autores

Animal Genetic Resources/Resources génétiques animales/Recursos genéticos animales es una revista trilingüe, publicada tres veces al año electrónicamente en internet (http://journals.cambridge.org/AGR) y de forma impresa. Los principales trabajos son publicados en inglés, francés y español, con resúmenes en estos tres idiomas. La revista viene siendo publicada desde el año 1983 y todas las ediciones pasadas están disponibles en el enlace: http://dad.fao.org/cgi-bin/EfabisWeb.cgi?sid=-1,refcat_50000044

La revista invita a la presentación de trabajos desde cualquier parte del mundo. Aquellos autores que no posean un nivel elevado en alguno de las tres lenguas aceptadas, les solicitamos que busquen la ayuda necesaria en este sentido antes de remitirnos sus manuscritos.

Misión

La revista proporciona un foro internacional para la publicación de trabajos relacionados con la gestión de los recursos genéticos animales para la alimentación y la agricultura (AnGR). En concreto, se tratan las siguientes áreas: caracterización fenotípica y molecular; sondeo y seguimiento; desarrollo (mejora genética); utilización sostenible; desarrollo de las capacidades de los ganaderos y las comunidades de pastores; y políticas e instituciones.

Los editores aceptan todos los trabajos enviados que traten sobre los temas mencionados anteriormente. Trabajos relativos a razas y tecnologías que contribuyan a la gestión sostenible de los sistemas de producción con ingresos medios y bajos en el mundo, que comprenden la mayor parte de las tierras dedicadas a la producción ganadera y la mayor parte de la producción del ganado, que son los que ostentan mayor grado de interés.

La revista apoya la implementación del Plan de Acción Mundial sobre los Recursos Zoogenéticos, el marco de trabajo acordado para la gestión de los AnGR y el Convenio sobre la Biodiversidad.

Descargo de responsabilidad

Los puntos de vista expresados en los trabajos publicados en Animal Genetic Resources/Resources génétiques animales/Recursos genéticos animales son solamente las opiniones del autor o autores y, por tanto, no reflejan necesariamente las políticas de la FAO o los puntos de vista de los editores o de las instituciones a las que dichos autores pertenecen.

Evaluación de expertos

Los manuscritos enviados para su publicación en Animal Genetic Resources/Resources génétiques animales/Recursos genéticos animales serán estudiados minuciosamente por parte de dos críticos externos. Lo ideal es que los manuscritos sean evaluados por los críticos externos y por los editores, recayendo la decisión final acerca de los mismos sobre los editores.

Categorías de los trabajos

Trabajos sobre investigación – Se tomarán en consideración para su publicación en Recursos genéticos animales los trabajos relacionados con la gestión de los AnGR. Se invita a los autores a incluir las fotografías de alta calidad pertinentes relativas al trabajo presentado en sus manuscritos. Si las fotografías ilustran animales, éstas deben mostrar el entorno de producción primario al que estos animales se han adaptado.

Trabajos de revisión – Se podrán tomar en consideración ocasionalmente aquellos trabajos que presenten una revisión del desarrollo a nivel de nacional, regional o mundial en uno o más aspectos de la gestión de los AnGR. Estos trabajos podrán incluir las revisiones del estado actual de campos específicos de la gestión de los AnGR.

Artículos específicos **–** Los artículos relacionados con los temas de la revista serán publicados cuando los editores lo consideren oportuno.

Otros trabajos publicados**:** Se invita a los lectores a enviar la siguiente información a la dirección de correo electrónico: AnGR-Journal@fao.org

- Revisiones o propuestas de libros.
- Conclusiones y recomendaciones resultantes de reuniones, talleres y conferencias relevantes.
- Anuncios de cursos de capacitación y eventos a nivel nacional, regional o internacional.

Originalidad y copyright

Para poder ser publicado en la revista Recursos genéticos animales, el manuscrito deberá no haber sido publicado previamente o estar bajo estudio para ser publicado. (Los datos que hayan sido publicados previamente podrán ser usados en la revista con precaución y siempre y cuando se obtenga el permiso necesario). Antes de la publicación, el autor del manuscrito deberá firmar y entregar, en su nombre y en el de los co-autores, una autorización y un formulario de consentimiento de transferencia a la editorial. Este formulario se enviará al autor junto con la prueba del artículo a publicar.

Autoría

Los artículos que tengan múltiples autores serán revisados bajo el supuesto de que todos los autores han contribuido a la investigación descrita en el artículo y aprueban tanto el artículo en su totalidad como el envío y la publicación de éste. Contribución al trabajo presentado supone la concepción y el diseño del proyecto, los resultados de los experimentos y/o el análisis e interpretación de los datos. Los autores deberán haber contribuido sustancialmente al borrador o a la revisión de dicho trabajo.

Presentación del Manuscrito

Todos los manuscritos deberán enviarse online, y sin coste alguno para el autor, a través de la página Web: http://journals.cambridge.org/AGR.

Posteriormente al envío del manuscrito, se mandará acuse de recibo junto con un número de referencia y el manuscrito será presentado para ser estudiado. Para toda correspondencia relacionada con el manuscrito, se deberá incluir el número de referencia mencionado.

Se deberán seguir las siguientes instrucciones (para más información, ir a la sección "Preparación y estilo de manuscrito"):

- Los manuscritos se presentarán en ingles, francés o español. Si el manuscrito está escrito en francés o español se deberá incluir un resumen, así como palabras clave en el mismo idioma además del inglés. Todos los artículos publicados presentarán un resumen en inglés, francés y español. Se agradecerá el envío del resumen en los tres idiomas con objeto de reducir gastos de traducción y acelerar el proceso del manuscrito.
- El formato deseado de documento para la presentación es Microsoft Word. No se aceptarán manuscritos enviados en Word Perfect u otros procesadores de texto. Los cuadros se incluirán al final del documento, siguiendo el orden indicado por los marcadores de posición dentro del texto.
- Las figuras deberán presentarse en documentos separados con una resolución apropiada (Para más información ver "Preparación y estilo de manuscrito").
- Se deberá presentar una carta de presentación en un documento por separado. La carta deberá indicar la categoría bajo la que el manuscrito se presenta (Ver apéndice 1) y los datos del autor (número de teléfono, fax, y dirección de correo electrónico).
- Los nombres de los archivos enviados deberán indicar el nombre completo o abreviado del autor principal.
- No se requiere ni deberá enviarse copia en papel del manuscrito, de los cuadros o de las figuras.

Tenga en cuenta que toda correspondencia en relación con los manuscritos presentados y analizados se hará exclusivamente con el autor principal.

Preparación y estilo del manuscrito

El formato del manuscrito deberá tener un espaciamiento doble entre líneas. Las páginas deberán estar numeradas, siendo la página número uno la que lleva el título del artículo. Los márgenes de las páginas deberán tener al menos 2.5 cm. en todas sus caras. La letra debe ser estilo "Arial".

Autores y afiliaciones – Los nombres y afiliaciones de los autores deberán presentarse en el formato siguiente:

E.C. Quispe[1], T.C. Rodríguez[2], L.R. Iñiguez[3] and J.P. Mueller[4]

[1]Universidad Nacional de Huancavelica, Huancavelica, Perú; [2]Universidad Mayor de San Andrés, La Paz, Bolivia; [3]Cochabamba, Bolivia; [4]Instituto Nacional de Tecnología Agropecuaria, Bariloche, Argentina.

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El título abreviado tendrá un máximo de 50 caracteres y aparecerá en la página 1 del manuscrito.

El ***resumen*** no deberá tener estructura o subtítulos y deberá proporcionar al lector una sinopsis que sea independiente del documento. Deberá incluir una breve introducción, la metodología usada, los resultados obtenidos y las conclusiones. El resumen no deberá exceder de 210 palabras en inglés y 250 palabras en francés y español. El resumen deberá ser seguido de tres a cinco palabras clave separadas por una coma. Tanto el resumen como las palabras clave se escribirán en el mismo idioma del manuscrito además del inglés.

El ***texto principal del manuscrito*** deberá empezar en la página número 3 y las referencias deberán comenzar en una página nueva. Las líneas de texto deberán estar numeradas y el manuscrito estructurado con encabezamientos numerados consecutivamente (eje. 1., 1.1, 1.1.1 etc.). Es importante evitar el uso de referencias cruzadas cuando se use la numeración de los encabezamientos, en cuyo caso la editorial eliminará la numeración y aplicará los estilos de encabezamiento en la versión final.

Adicionalmente, los trabajos de investigación deben incluir los siguientes encabezamientos: ***Materiales y métodos, Resultados, Discusión y Conclusiones***.

La ***extensión máxima*** del texto principal del manuscrito no deberá exceder de 10 páginas (8.500 palabras aprox.). En caso de que el texto sea corto, éste no deberá exceder de una página (750 palabras ó 500 palabras si se incluye una imagen).

Los Cuadros deberán ser numerados consecutivamente tal y como están citados en el texto (Cuadro 1, 2 etc.). Cada cuadro deberá aparecer en una página distinta (al final del documento) con la numeración y título arriba y las anotaciones o comentarios debajo del mismo.

Las figuras se numerarán consecutivamente tal y como están citadas en el texto del documento (Figura 1, 2, etc.). Se deberán usar caracteres en cursiva para apartados a, b, c, etc. Cada figura deberá incluir una leyenda. En caso que corresponda, las figuras se deberán enviar en archivos con formato TIFF o EPS, preferiblemente con el mismo tamaño con el que serán reproducidos o publicados. Las ilustraciones o material gráfico deberán enviarse en blanco y negro con una resolución de 1200 dpi; las combinaciones de material gráfico con una resolución de 800 dpi; el material gráfico en modelo de semitono en blanco y negro deberá guardarse bajo el modo "escala de grises" con una resolución de 300 dpi; el material gráfico en modelo de semitono a color se guardará bajo modo "CMYK" con una resolución de 400 dpi. Se deberán obtener todos los permisos necesarios.

Abreviaturas y el sistema internacional de unidades (SI) – No se recomienda el uso de abreviaturas excepto aquellas extensamente utilizadas. Las abreviaturas deberán usarse sólo en caso de que mejoren la comprensión del manuscrito. Los acrónimos deberán ser escritos en palabras completas la primera vez que se mencionen. Se usarán las medidas del sistema métrico internacional (SI).

Lista de agradecimientos

En esta sección el autor deberá hacer mención a la ayuda económica recibida, por parte de las agencias de financiación u otras fuentes,

para la realización del trabajo documentado en el manuscrito. También se podrán incluir, en esta sección, los agradecimientos a las personas que contribuyeron a la investigación pero que no aparecen como autores.

La lista de agradecimientos deberá aparecer después del texto principal antes de las referencias. En caso de que no haya agradecimientos, la palabra "ninguno" seguirá al encabezamiento "Lista de agradecimientos".

Declaración de interés

Existe conflicto de intereses cuando un autor tiene intereses que pudieran influir de forma inapropiada en su opinión o juicio, incluso si su opinión no ha sido finalmente influenciada. Por esta razón, los autores deberán revelar conflictos de intereses potenciales de forma que se pueda evaluar sobre sus efectos. En el momento en que se envíe el manuscrito, los autores deberán revelar cualquier acuerdo o conexiones económicas que puedan tener, que sean pertinentes al manuscrito enviado y que puedan ser percibidas como potencial amenaza a la imparcialidad del documento. También deberán declararse los intereses no-financieros que pudieran ser relevantes en este contexto. En caso de que no haya intereses relevantes, deberá también indicarse. Este requerimiento será aplicable a todos autores del documento y a todas las categorías de documentos.

Referencias

Toda referencia presente en el texto deberá aparecer en la lista de referencias y, de la misma manera, cada referencia de la lista deberá haber sido citada por lo menos una vez en el texto. Las referencias deben ir en orden alfabético del apellido del autor, seguido por el año.

Ejemplos:

1. *Ejemplo en el caso de una referencia de una revista*:
   Köhler-Rollefson, I. 1992. The camel breeds of India in social and historical perspective. *Animal Genetic Resources Information* 10: 53–64.
2. *Cuando se trate de más de un autor*:
   Matos, C.A.P., Thomas, D.L., Gianola, D., Tempelman, R. J. & Young, L.D. 1997. Genetic analysis of discrete reproductive traits in sheep using linear and non-linear models: 1. Estimation of genetic parameters, *Journal of Animal Science* 75: 76–87.
3. *En el caso de un libro o de una publicación ad hoc, por ejemplo informes, tesis, etc*.
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