

## **Understanding the Effect of the Environmental Conditions on the Suitability of a Breed for Different Agro-Ecological Zones**

*Maria Lozano-Jaramillo<sup>1\*</sup>, John Bastiaansen<sup>1</sup>, Tadelle Dessie<sup>2</sup>, Hans Komen<sup>1</sup>*

*<sup>1</sup>Wageningen University & Research Animal Breeding and Genomics, PO Box 338, 6700 AH Wageningen, The Netherlands*

*\*[maria.lozanojaramillo@wur.nl](mailto:maria.lozanojaramillo@wur.nl) (Corresponding Author)*

*<sup>2</sup>International Livestock Research Institute, P. O. Box 5689 Addis Ababa, Ethiopia*

### **Summary**

Predicting suitability of breeds for a production system can be challenging in livestock. Most attempts to introduce exotic breeds in low input systems were unsuccessful mainly due to the antagonistic environmental conditions. Knowledge of the environmental conditions that are shaping the breed would be needed to elucidate their suitability to different locations. Predictive habitat distribution models use the current climatic conditions of a breed to make predictions of the potential distribution of the breed. A methodology was developed to predict breed suitability for different agro-ecological zones based on GIS tools and PHD models. This methodology was tested on distribution data of two introduced chicken breeds in Ethiopia: the Koekoek, originally from South Africa, and the Fayoumi, originally from Egypt. Results from cross-validation based on the current distribution of the breeds showed this methodology to be effective in predicting breed specific environmental suitability. Furthermore, for both breeds the significant climatic factors that shape the breeds distribution were similar between the suggested distribution area, and the environment from which the breeds originated in South Africa and Egypt. This novel methodology applied to livestock research, allows for better decisions in introduction programs and the design of testing schemes, and increases our understanding of the role of the environment in livestock productivity.

*Keywords: agro-ecology, breeding programs, distribution models, local adaptation*

### **Introduction**

Indigenous breeds are exposed to natural selection process, which allow them to acquire traits that shape them to be better suited to their environment when compared to introduced breeds. They are known to be locally adapted to specific environmental conditions, as well as tolerant to different parasites and diseases (Mirkena et al., 2010). In terms of productivity, however, exotic breeds show an advantage over the local breeds (Kosgey et al., 2006). Better prediction of the suitability of a breed to environmental circumstances would be beneficial.

The application of habitat distribution models is a tool that can be applied to make inferences on the potential distribution of a breed taking into account different climatic variables (Thomas et al., 2004; Keith et al., 2008; Phillips and Dudík, 2008; Loarie et al., 2009). Application of predictive habitat distribution models (PHD) to predict suitability of breeds in livestock production systems has not been done.

Here we test the predictive habitat distribution models on two different introduced poultry breeds in Ethiopia. Ethiopia is an ecologically highly diverse country with a broad range of contrasting agro-ecologies (Fig.1) defined by altitude, temperature and rainfall

(Mengistu, 2003). The methodology was used to 1) make predictions for two breeds about their potential suitable habitat range in Ethiopia, and to 2) indicate which bio-ecological variables explain the differences in the areas where the different chicken breeds of chicken occur. Having a better understanding of the environments' role will improve the design of introduction schemes, and will help to better understand the factors that may cause a difference in breed productivity between environments.

## **Material and methods**

### **Environmental and breed data**

Considering all of Ethiopia, we used a total of 161 breed locations, 62 for the Fayoumi breed, and 99 for the Koekoek breed (Fig. 1b), obtained from the Ethiopian Institute of Agricultural Research (EIAR). From WorldClim (Hijmans et al., 2005), and the Harmonized World Soil Database v 1.2), we collected a total of 21 variables available at a 1km by 1km resolution. The environmental data included 19 bioclimatic variables and an elevation layer representing current climatic conditions. These 20 layers are commonly used as indicators of annual trends in seasonality, temperature and precipitation. In addition, a land cover layer, total cultivated land, was included as a proxy to anthropogenic intervention and agricultural systems, as smallholders presence and poultry density are closely linked in Ethiopia (Tadelle, 2003; Mwacharo et al., 2013).

### **Model building and predicting breed occurrence**

To implement the PHD models, we used the maximum entropy algorithm in Maxent (Phillips et al., 2006). The probability of suitability was presented on a map. We validated the model using the receiver operating characteristic (ROC) curve (known areas of presence predicted absent, Phillips et al., 2006).

For each breed independently, we generated a map of the potential distribution. For each breed we identified the environmental variables that had the highest predictive contribution to the model and evaluated these variables against the environmental background of the breed.

### **Cross-validation**

To determine if the model predictions could predict breed suitability, we divided the country in a total of 110 cells. For each breed independently, the localities within each cell where the breed was present were removed from the training data set, and the model was fitted to predict a probability of occurrence for that same cell. This was done cell by cell for all of the cells that included the occurrence data.

For the cells where the breed was not present, a set of random localities, defined as absent localities was developed and the predicted probability for each of the cells was estimated as the cells with occurrence data.

To evaluate the ability of the model to identify suitable environmental conditions, we first selected the cells with reported poultry density greater than 10 individuals per square kilometer (Robinson et al., 2014). Then the predicted probabilities for the cells with occurrences and the cells with absences were compared and visualized with a density plot. A t-test was applied to test whether both groups were significantly different.

Data handling and Maxent analyses were conducted with R version 3.2.2 (R

Development Core Team, 2016) running on RStudio version 0.99.902 (RStudio Team, 2015).

## **Results**

### **Prediction of breed suitability and cross-validation**

Predicted suitability for cells where the breed is present was greater than the predicted suitability for cells where the breeds is absent ( $P < 0.05$ ). For both breeds, the model predicted that suitable environmental conditions exist beyond the current boundaries of the breed distribution (Fig. 2). The area under the ROC curve for the model predicting the potential distributions of the Fayoumi and Koekoek breeds were close to one (0.981 and 0.975 respectively), indicating that the model performed well.

### **Most important climatic conditions**

The variable explaining most of the variation in suitability for the Fayoumi breed (43.7%; Table 1) was associated with total cultivated land. The next two axes jointly accounted for 26.3% of the environmental variation (Table 1) and were associated with precipitation. The variable explaining most of the variation for the Koekoek breed (PC1; 18.1%; Table 1) was associated with minimum temperature of the coldest month. The next two axes jointly accounted for 21.6% of the variation (Table 1) and were associated with mean temperature of the warmest quarter, and the range of mean monthly temperature.

## **Discussion**

Our results suggest that each breed occupies different climatic environments; the Fayoumi breed is kept in areas where there is a higher percentage of land used in agriculture, and where there is higher precipitation, whereas the Koekoek breed is kept in colder environments with larger temperature fluctuation. Even though both breeds are kept in overlapping areas of the country, it should be noted that there are some areas where they do not occur together. The Koekoek breed is kept in some localities associated with tepid to cool moist and sub-moist mid-highlands. The Fayoumi breed is kept in tepid to cool humid mid-highlands, and hot to warm moist lowlands. The distribution models also suggest that there are more areas of the country where the Fayoumi and the Koekoek breeds could be suitable for poultry production. This result can be informative in deciding which breed to keep depending on the region.

Differences on the current distribution of breeds can be attributed to both natural and non-natural processes, where anthropogenic influence, as well as the environment where the breeds are kept can play an important role in shaping local adaptation (Mariane and Egito, 2002). Part of this biological variation can be explained by the breeds' origin, and where environmental selective pressures have shaped their adaptation to specific environments. The Fayoumi is a breed of Egyptian origin (Hossaryl and Galal, 1994), while the Koekoek originated in South Africa (Grobbelaar et al., 2010). A study that assessed the genetic diversity of chicken populations in Africa, Asia and Europe revealed that the Fayoumi breed was grouped with chickens from the Mediterranean, while the Koekoek shared a cluster with eastern European breeds and broiler chickens (Lyimo et al., 2014). This genetic variability also suggests that breeds might respond differently in different climates.

In conclusion, this work showed the utility of habitat distribution models in predicting

livestock suitability to different agro-ecologies. Understanding the environmental requirements of different breeds, including the knowledge of which environmental variables are determining the difference in performance, is an important tool to support higher productivity in particular regions (Arthur and Albers, 2003). The PHD models allows for better decisions in introduction programs and in the design of testing schemes, and increases our understanding of the role of the environment in livestock productivity.

## Figures

*Table 1. Selected environmental variables with their percent contributions to the prediction model.*

<b>Breed</b>	<b>Environmental variable</b>	<b>Percentage contribution</b>
<b>Koekoek</b>	Min Temperature of Coldest Month	18.1
	Mean Temperature of Warmest Quarter	11.9
	Mean Diurnal Range	9.7
<b>Fayoumi</b>	Total cultivated land	43.7
	Precipitation of Driest Quarter	16.9
	Precipitation of Coldest Quarter	9.4

*Figure 1. Map of Ethiopia showing the 18 major agro-ecological zones based on temperature and precipitation.*

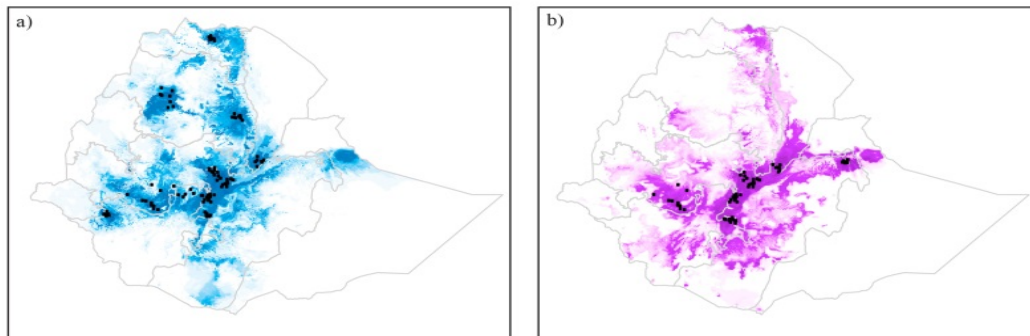


Figure 2. Suitability predictions for (a) Koekoek, and (b) Fayoumi breeds in Ethiopia. Predicted areas are shaded; darker colors denote areas of higher climatic suitability. Observed localities used to build the model are shown in black dots.

## List of References

- Arthur, J. A., and G. A. Albers. 2003. Industrial perspective on problems and issues associated with poultry breeding. *Poultry genetics, breeding and biotechnology*:1-12.
- FAO/IIASA/ISRIC/ISSCAS/JRC. 2012. Harmonized World Soil Database (version 1.2), FAO, Rome, Italy and IIASA, Laxenburg, Austria. Available at: <http://www.fao.org/soils-portal/soil-survey/soil-maps-and-databases/harmonized-world-soil-database-v12/en/> (accessed February 2017).
- Grobbelaar, J., B. Sutherland, and N. Molalagotla. 2010. Egg production potentials of certain indigenous chicken breeds from South Africa. *Animal Genetic Resources/Ressources génétiques animales/Recursos genéticos animales* 46:25-32.
- Hijmans, R. J., S. E. Cameron, J. L. Parra, P. G. Jones, and A. Jarvis. 2005. Very high resolution interpolated climate surfaces for global land areas. *International Journal of Climatology* 25(15):1965-1978.
- Hossaryl, M., and E. Galal. 1994. Improvement and adaptation of the Fayoumi chicken. *Animal Genetic Resources Information* 14:33-39.
- Keith, D. A., H. R. Akçakaya, W. Thuiller, G. F. Midgley, R. G. Pearson, S. J. Phillips, H. M. Regan, M. B. Araújo, and T. G. Rebelo. 2008. Predicting extinction risks under climate change: coupling stochastic population models with dynamic bioclimatic habitat models. *Biology Letters* 4(5):560-563.
- Kosgey, I., R. Baker, H. Udo, and J. Van Arendonk. 2006. Successes and failures of small ruminant breeding programmes in the tropics: a review. *Small Ruminant Research* 61(1):13-28.
- Loarie, S. R., P. B. Duffy, H. Hamilton, G. P. Asner, C. B. Field, and D. D. Ackerly. 2009. The velocity of climate change. *Nature* 462(7276):1052-1055.
- Lyimo, C., A. Weigend, P. Msoffe, H. Eding, H. Simianer, and S. Weigend. 2014. Global diversity and genetic contributions of chicken populations from African, Asian and European regions. *Animal genetics* 45(6):836-848.
- Mariante, A. d. S., and A. Egito. 2002. Animal genetic resources in Brazil: result of five centuries of natural selection. *Theriogenology* 57(1):223-235.
- Mengistu, A. 2003. Country Pasture/Forage Resource Profiles, Ethiopia. Available at: [www.fao.org/AG/agp/agpc/doc/Counprof/Ethiopia/Ethiopia.htm#7.%20RESEARCH](http://www.fao.org/AG/agp/agpc/doc/Counprof/Ethiopia/Ethiopia.htm#7.%20RESEARCH)

- %20AND%20DEVELOPMENT%20ORGANIZATIONS%20AND (accessed February 2017).
- Mirkena, T., G. Duguma, A. Haile, M. Tibbo, A. Okeyo, M. Wurzinger, and J. Sölkner. 2010. Genetics of adaptation in domestic farm animals: A review. *Livestock Science* 132(1):1-12.
- Mwacharo, J. M., G. Bjørnstad, J. L. Han, and O. Hanotte. 2013. The History of African Village Chickens: an Archaeological and Molecular Perspective. *African Archaeological Review* 30(1):97-114. (journal article) doi: 10.1007/s10437-013-9128-1
- Phillips, S. J., R. P. Anderson, and R. E. Schapire. 2006. Maximum entropy modeling of species geographic distributions. *Ecological modelling* 190(3):231-259.
- Phillips, S. J., and M. Dudík. 2008. Modeling of species distributions with Maxent: new extensions and a comprehensive evaluation. *Ecography* 31(2):161-175.
- R Development Core Team. 2016. R: a language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. Available at: <http://www.R-project.org>.
- Robinson, T. P., G. R. W. Wint, G. Conchedda, T. P. Van Boeckel, V. Ercoli, E. Palamara, G. Cinardi, L. D'Aiotti, S. I. Hay, and M. Gilbert. 2014. Mapping the Global Distribution of Livestock. *PLoS ONE* 9(5):e96084. doi: 10.1371/journal.pone.0096084
- RStudio Team. 2015. RStudio: Integrated Development for R. RStudio, Inc., Boston, MA URL <http://www.rstudio.com/>.
- Tadelle, D. 2003. Phenotypic and genetic characterization of local chicken ecotypes in Ethiopia.
- Thomas, C. D., A. Cameron, R. E. Green, M. Bakkenes, L. J. Beaumont, Y. C. Collingham, B. F. Erasmus, M. F. De Siqueira, A. Grainger, and L. Hannah. 2004. Extinction risk from climate change. *Nature* 427(6970):145-148.