254

Modelling global livestock diversity

A fuzzy cognitive mapping approach

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Modelling global livestock diversity

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Abstract
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For modelling global trends in agrobiodiversity better insight in the relationship between drivers (and related pressures) and agrobiodiversity is needed. In a previous study of the authors a number of indicators for genetic diversity were proposed as being suitable for modelling. In this working document it was investigated if a global agrobiodiversity map for livestock could be produced based on one of these earlier suggested indicators. The Global Domestic Animal Diversity Information System (DAD-IS) was interrogated for one livestock species (cattle) to investigate whether sufficient data of good quality is available to produce such a global map. Additionally, a fuzzy cognitive mapping approach was used to make a qualitative description of livestock diversity in relation to drivers of change. In the FCM 21 factors were identified by the workshop participants to describe the livestock diversity system, of which 10 appeared to be most influential. For these most important factors a list of relevant (proxy) indicators with their potential for use was suggested. These suggested indicators could be the basis for further research in which the so-called archetype methodology could be used to get insight in hotspots of livestock diversity.

Key words: agrobiodiversity, livestock diversity, modelling, cattle, fuzzy cognitive mapping, drivers of change indicators.

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Contents

Summary

Agrobiodiversity is relevant for food security (Thrupp, 1998; Munzara, 2007), although the relationship between these two notions is complex. In order to meet the growing demand for food, uniformity of crop varieties and livestock breeds has grown with the purpose of increasing productivity. However, this development carries risks. Agrobiodiversity loss makes food production more vulnerable to pests and diseases and to a changing climate with its predicted drought, temperature increase and weather unpredictability. In a way, short term food security can be regarded as coming at the expense of long term food security. Tracking the change in global agrobiodiversity is a step towards a better understanding of these risks involved.

Trends in agrobiodiversity loss can be analysed through monitoring and modelling. Monitoring has advantages over modelling as it is an objective way to measure the status of agrobiodiversity. However, developing easy-to-interpret indicators for agrobiodiversity is difficult and especially the lack of monitoring data is a persistent and globally occurring problem. Modelling might complement conventional monitoring. In addition, modelling enables us to make projections in the future for different socioeconomic scenarios and to assess the consequences for functions such as food security, environmental quality and landscape.

This report explores possibilities towards the development of a prototype model to assess past, present and future trends in agrobiodiversity, in spite of the lack of complete agrobiodiversity data. In this context, insight is needed in those factors that largely determine the change in agrobiodiversity. Additionally, insight is needed in data availability both of genetic diversity and driving force indicators.

First, it was investigated if a global agrobiodiversity map could be produced, expressed in one of the indicators as reviewed in Buiteveld *et. al.*, 2009. In particular 'the Share of breeding female population between introduced and native livestock breeds' (EEA, 2007) was recognized as a suitable indicator for monitoring and modelling. The indicator is a proxy to assess the genetic diversity of these species, as it clearly indicates the ratio between non-native and native breed's populations. An increase of the proportion of non-native breeds populations generally happens at the expense of native breeds populations and indicates a potential loss of biodiversity. The Global Domestic Animal Diversity Information System (DAD-IS) was interrogated for one livestock species (cattle) to investigate whether sufficient data of good quality is available.

Second, the Fuzzy Cognitive Mapping (FCM) methodology was used to describe the relationship between agrobiodiversity and a few economic, cultural, socio-political, ecological factors that would enable us to track, explain and predict the change in agrobiodiversity on the basis of data that do exist from the socioeconomic field.

Interrogating the DAD-IS database (www.fao.org/dad-is) revealed that the production of a global agrobiodiversity map is currently not feasible. The indicator could be calculated for cattle in only 9 countries, mainly restricted to Europe. The database lacks too many data, and is far from complete. Also for the near future it is probably unrealistic to expect that the majority of countries will make much progress with reporting population data. To improve data collection FAO developed draft guidelines on surveying and monitoring of animal genetic resources (FAO, 2011a).

The Fuzzy Cognitive Mapping (FCM) approach was identified as a promising method for analysing the (socio-economic) drivers of change that determine the state and change in global and regional agrobiodiversity. It brought together the expert knowledge in an explicit way and improved our understanding of how the livestock diversity system might function. In the FCM analysis 21 drivers/factors were identified. The expert group recognized 10 of these as most influential on agrobiodiversity levels: quantitative demand, organisation of the breeding sector, intensification/specialisation, farmer's knowledge, infrastructure, demography, extent of market integration, policy support, knowledge system and vertical and horizontal integration. However, the FCM showed a rather 'Western view'. To validate the FCM and its suitability as a conceptual model it needs to be tested, for instance in a range of diverse countries. To do this real data are needed. For many of the drivers identified data sets are lacking or are very difficult to obtain. Without data for the state of genetic diversity and the various driving factors it will be difficult to assess this.

For the most important factors in the FCM a list of relevant (proxy) indicators with their potential for use was suggested. These suggested indicators could be the basis for further research in which the so-called archetype methodology (UNEP, 2007) could be used to get insight in hotspots of agrobiodiversity and agrobiodiversity loss. However, even if it is assumed that the right set of indicators for drivers is selected here, data availability will also remain a problem for proceeding further with a cluster analysis. Hence, currently the construction of an 'agrobiodiversity archetype' map based on the drivers identified in the FCM is still complicated.

Adequate models require proper expert input and testing in the field using case studies. This simple pilot study indicated that there are possibilities to model agrobiodiversity in general, but it takes a second phase to see if there are sufficient alternative socio-economic indicators available to develop a global agrobiodiversity map and it takes time and budget to carry out the necessary case studies for validation. If these conditions can be met, it is worth to proceed with the second phase.

The research builds on earlier work executed within the Convention of Biological Diversity (CBD), Food and Agriculture Organization (FAO) and Streamlining European Biodiversity Indicators Project (SEBI). Earlier studies conducted by Centre for Genetic Resources, the Netherlands (CGN) and Netherlands Environmental Assessment Agency (PBL) resulted in a number of reports including evaluation of the current status of agrobiodiversity in the Netherlands (Windig *et. al.*, 2007) and evaluation of indicators for livestock and crop diversity (Eaton *et. al.*, 2006, Buiteveld *et. al.*, 2009).

1 Introduction

1.1 Background

On a global level crop and livestock production is increasingly dominated by a small number of highly productive varieties and breeds. A myriad of local varieties are replaced by highly productive ones (FAO, 2007; 2009). Loss of diversity has also been referred to as genetic erosion and may form a hazard for sustainable agricultural production and food security, agricultural products, livelihoods and income. It is for these threats that it is important to have an idea on the status of genetic biodiversity (agrobiodiversity) within a particular agricultural production system in the past, present and future. Trends in agrobiodiversity loss can be analysed through monitoring and modelling. Monitoring has advantages over modelling as it is an objective way to measure the status of agrobiodiversity. However, developing easy-to-interpret indicators for agrobiodiversity appeared difficult and the lack of monitoring data is a persistent, globally occurring problem. For the time being, modelling could be a promising alternative to assess the present state of agrobiodiversity for countries and regions where conventional monitoring of agrobiodiversity is currently absent. Modelling could be applied here, provided that sufficient data is available for validation. In addition, modelling enables us to make projections in the future for different socioeconomic scenarios and their consequences on functions such as food security, poverty, environmental quality, landscape.

The role of agrobiodiversity in providing food security is highly relevant (Thrupp, 1998; Munzara, 2007), although the relationship between these two is complex. Food security is determined by food production (yield) but also by stability and resilience of the production system in relation to issues such as biotic/abiotic stresses and socio-economic variability. Agricultural intensification results in increasing uniformity in crop varieties and animal breeds. Homogenization has advantages such as high productivity, economics of scale, easy processing and management but carries risk in the short and long-term. It makes production systems increasingly vulnerable both from a genetic and economic perspective. It often also requires high inputs such as fertilizers, pesticides, medicines, water/feed use etc. Varieties/breeds differ enormously in production but also in robustness for disturbances. High productive varieties/breeds are often less suitable in marginal areas with variable productions conditions, while local varieties/breeds are found to be more stable in marginal environments. Diversity within crops and livestock makes production systems more resilient to pests, diseases, drought, feed shortage and changing climatic conditions etc. A better insight in the relationship between agrobiodiversity and food security would allow us to assess the changes in agrobiodiversity under growing intensification and predict what this means for the food security.

1.2 Aim of this research

The relationship between drivers/pressures and agrobiodiversity is complex because the use of agrobiodiversity takes place in the social system. In other words, the state of agrobiodiversity is determined by a complex of economic, socio-political and technological factors and their interactions and feedback loops, in addition to the underlying agro-ecological conditions. Modelling agrobiodiversity therefore requires its own approach which is different from the modelling approach for wild biodiversity (Alkemade *et. al.*, 2009). Although wild

biodiversity is also affected by economic and socio-political drivers, the major difference between agrobiodiversity and wild biodiversity is in the significance of human management.
This report explores possibilities towards the development of a prototype model on patterns of agrobiodiversity. The research described in this report has been structured according to the following questions:

- Can we produce an agrobiodiversity map based on previously proposed genetic diversity indicators and is sufficient good quality data available to do this? In a previous study a review for potential indicators for monitoring agrobiodiversity (Buiteveld *et. al.*, 2009) was made and a number of indicators were assessed as suitable for modelling. In particular 'the share of breeding female population between introduced and native livestock breeds' (EEA, 2007) was recognized as a suitable indicator for monitoring and modelling. The indicator is a proxy to assess the genetic diversity of these species, as it clearly indicates the ratio between non-native and native breeds' populations. An increase of the proportion of non-native breeds populations generally happens at the expense of native breeds' populations and indicates a potential loss of biodiversity. In this study the genetic indicator was used to produce a global agrobiodiversity map for cattle showing the current situation.
- Can we develop a better understanding of the relationship between drivers (and related pressures) and resulting agrobiodiversity? For this purpose an influence diagram can be developed that will describe the relationship between agrobiodiversity and the economic, cultural, socio-political, ecological and scientific-technological determinant factors including their mutual interactions and feedbacks. To get a better insight in these relationships the fuzzy cognitive mapping (FCM) approach can be applied. Fuzzy cognitive mapping is a tool to create a conceptual model based on people's or expert's knowledge. In this study the FCM tool, which was applied in a participatory workshop setting, was used to analyse how experts perceive the agrobiodiversity system and to identify the most important drivers/components of this system. Cattle were chosen as a model species.
- Can we identify relevant indicators (or proxies) for the most important determinants/interactions? Here the FCM, which was created based on expert information, served as a basis for defining relevant indicators for modelling agrobiodiversity.

The ultimate goal of this type of research is to develop a model for agrobiodiversity, which will enable us to assess the past, current (and future) status of agrobiodiversity. Such a model should be applied globally and could be used as an alternative to conventional monitoring.

In future research the so-called 'archetype approach' can be followed to develop an agrobiodiversity model. The archetype methodology is developed by UNEP (2007) for identifying and mapping patterns of vulnerability of people in relation to environmental and socio-economic changes. Such a methodology could also be used to map hotspots of agricultural biodiversity or biodiversity loss by examining the identified relationship between (loss of) agrobiodiversity and driving forces causing this. This approach results in an 'archetype agrobiodiversity' map. Such a map can be produced by performing a cluster analysis of relevant indicators which explores whether similar archetypical patterns of the agrobiodiversity can be found around the world. It may also allow future projections of the state of agrobiodiversity. However, to be able to perform such a cluster analysis for the current situation, data (both on driving force and genetic diversity indicators) should be available preferably on a sub-national level.

The focus of the present study is on the three research questions mentioned above, which should be answered before it can be decided to proceed further with a cluster analysis.

The research builds on earlier work executed within the Convention of Biological Diversity (CBD), Food and Agriculture Organization (FAO) and Streamlining European Biodiversity Indicators Project (SEBI). Earlier studies conducted by Centre for Genetic Resources, the Netherlands (CGN) and Netherlands Environmental Assessment Agency (PBL) resulted in a number of reports including evaluation of the current status of agrobiodiversity in the Netherlands (Windig *et. al.*, 2007) and evaluation of indicators for livestock and crop diversity (Eaton *et. al.*, 2006, Buiteveld *et. al.*, 2009).

1.3 Definition of agrobiodiversity

Agrobiodiversity 'encompasses the variety and variability of animals, plants and micro-organisms which are necessary to sustain key functions of the agro ecosystem, its structure and processes for, and in support of, food production and food security' (FAO, 1999). With respect to biodiversity in agricultural species two levels can be distinguished. At the interspecific level, different combinations of crop, livestock, forest, fish or micro-organism species exist within farming systems. Diversity within these farming systems may be low (e.g. monoculture cropping systems or intensive animal husbandry) to high (e.g. multi-cropping systems, herding of multiple livestock species or mixed livestock-crop farming systems). At the intraspecific level different numbers of varieties or breeds may be cultivated per crop or livestock species, resulting (dependent on the diversity within and between the varieties or breeds) in low to high (genetic) diversity. This study focuses on genetic biodiversity in agro-ecosystems, especially the diversity at the intraspecific level of livestock.

1.4 Reading guide

Following the Introduction, Chapter 2 reports on data availability needed to investigate whether a global agrobiodiversity map can be produced based on the earlier suggested indicator for genetic diversity. In Chapter 3 the possibility of using a Fuzzy Cognitive Mapping (FCM) methodology is explored to further semi-quantify the relationships between agrobiodiversity and drivers or determining factors which are needed as input for modelling. In Chapter 4 relevant indicators (or proxies) are defined for the most important determinants/interactions based on the outcome of the FCM. The report finishes with conclusions and outlook on further research (Chapter 5).

2 An agrobiodiversity map

2.1 Introduction

In a previous study a review for potential indicators for monitoring agrobiodiversity (Buiteveld *et. al.*, 2009) was made and a number of indicators were proposed as being suitable for modelling. One of these indicators: the "share of breeding female population between introduced and native livestock breeds" (EEA, 2007) was recognized as a suitable indicator for monitoring and modelling. It clearly indicates the ratio between non-native and native breeds' populations. An increase of the proportion of non-native breeds' populations generally happens at the expense of native breeds' populations and indicates a potential loss of biodiversity. In this previous report the indicator was illustrated for cattle in two countries: the Netherlands and Germany, based on data from national databases. This genetic diversity indicator could be used to produce a global agrobiodiversity map showing the current situation of the state of genetic diversity in livestock.

This chapter reports on the results of data availability for calculating this indicator on a country level in order to produce such a global agrobiodiversity map. The global Domestic Animal Diversity Information System (DAD-IS at http://www.fao.org/dad-is/) was interrogated for one livestock species (cattle) to investigate whether sufficient data of good quality is available for calculating the proposed genetic diversity indicator developed by SEBI 2010 project (EEA, 2007). This indicator is defined as 'the share of breeding female population between introduced (i.e. non-native) and native breed species per country', as a proxy to assess the genetic diversity of these species. For evaluating this livestock genetic diversity indicator the following data should be available:

- Total number of breeding females of cattle breeds;
- Total number of breeding females of native cattle breeds.

Additionally it was tried to provide figures for different periods (+/- 2 years).

For calculating the SEBI indicator, all breeds were categorized as native or non-native. The local vs. transboundary breed classification used in DAD-IS could not directly be used for this. Here local breeds are not equal to native breeds, but mean that breeds are reported by one country only. Information on the native status of a breed was therefore derived in several ways. First, if information on native status given by the country itself was available this was used. Therefore national databases, if existing, were searched for information on the native status of a breed. For example, in the German database (www.tgrdeu.genres.de) the origin of the breeds is classified as imported or indigenous. Here we categorized imported breeds as non-native and indigenous as native. Second, if information on native status was not available from national databases, information in the DAD-IS database (breed origin and development descriptions) given by the country (NC) was used. Third, when information on native status could not be found in national databases nor in the DAD-IS database, descriptions of origin for breeds from literature were used.

We followed as much as possible the working definition of native given in the UK National Breed Inventory (Defra, 2006) to categorize the breeds. So if descriptions say that the breed is existing within the country of origin (including amalgamation of native breeds), the country is the primary environment for the development of the breed, the breed is present in the particular country for 40 years plus 6 generations, and not more than 20% of the genetic contributions come from animals born outside the country in any generation for the last 40 years plus 6 generations we considered the breed as native. However, it appeared to be very difficult to obtain information on all these criteria from literature.

2.2 DAD-IS database

The Domestic Animal Diversity Information System (DAD-IS at http://www.fao.org/dad-is) is maintained by the Food and Agriculture Organization of the United Nations (FAO). This information system, which was launched in 1996, enables National Coordinators for the management of Animal Genetic Resources to update their breed-related data online. The DAD-IS database covers more than 30 livestock species and includes data on the size and structure of breed populations. Together with the country reports it provided the basis for the State of the World's Animal Genetic Resources for Food and Agriculture, published in 2007 (FAO, 2007). In this 'State of the World' an assessment of trends in genetic diversity in livestock species is presented over the period 1999-2006. Countries are encouraged to regularly update their data to DAD-IS. The DAD-IS data are used by FAO to contribute to global biodiversity assessments. For example, FAO as a partner to the 2010 Biodiversity Indicators Partnership project, contributes information and analysis to the Biodiversity Outlook produced by the CBD. The most recent status and trends synthesis report of FAO is based on the DAD-IS data reported in 2010 (FAO, 2011b). In this document the state of reporting on animal genetic resources is given, the distribution of breeds and their risk status and trends in risk status of the reporting period are assessed.

2.3 Results

The DAD-IS database currently contains data from 182 countries and 37 species (FAO, 2011b). The total number of cattle breeds recorded in DAD-IS increased to 1348 in 2010. Although the number of breed populations that is recorded in DAD-IS has increased greatly, the number of breeds for which population data (population size, number of breeding females or males) are available is still rather low. For 393 cattle breeds out of 1348 population data was never reported. See Table 1 for number of cattle breeds reported worldwide per region.

Table 1 Number of cattle breeds reported worldwide.

SoW-AnGR region	**Number of breeds reported**[1]			
	Local[2]	**Regional transboudary**[3]	**International Transboundary**[4]	**Total**
Africa	172	35		
Asia	237	20		
Europe & the Caucasus	316	25		
Latin America & the Caribbean	143	6		
Near & Middle East	43	1		
North America	15	2		
South west Pacific	27	1		
World	953	90	111	1152

[1] *Excluding extinct breeds.*
[2] *Breeds reported by one country only.*
[3] *Breeds that occur only in one of the seven SoW-AnGR regions.*
[4] *Breeds that occur in more than one region.*
(adapted from FAO, 2011b)

Interrogating the DAD-IS database for cattle revealed us that for only 9 countries it was feasible to calculate the indicator as those countries provided population data for all breeds they reported (Figure 1). For calculating the indicator it was assumed that for these countries all existing breeds in the country were reported to the DAD-IS database. This was only checked for the Netherlands and Germany by comparing information existing in the countries such as national databases (resp. for the Netherlands through CGN staff and https://www.crv4all.nl and for Germany http://tgrdeu.genres.de/) with the data in the DAD-IS database.

All countries, except one, for which the SEBI indicator could be applied were European. In general the temporal coverage of data was low: the indicator could only be calculated for one or two periods (+/- 2 years) in a particular country. No complete data was available before 1994 to calculate the SEBI indicator.

Correct interpretation of the results given in Figure 1 will be difficult. First it was assumed that all breeds present in a country were also reported in the DAD-IS database. This was not checked for all countries given in Figure 1. If breeds are missing this will affect the share of native breeds population. Second, Figure 1 illustrate that countries define 'native' and 'non-native' differently. Here 98% of the breed populations are labelled as native in Germany, while in The Netherlands 98% of the breed populations are non-native. The reason for this is that in Germany Holstein Friesian is recognised as an indigenous breed according to information in their national database. The Netherlands considers Holstein Friesian as an international breed, originally originating from the Netherlands and Germany, but to a large extend introduced from the USA starting a few decades ago.

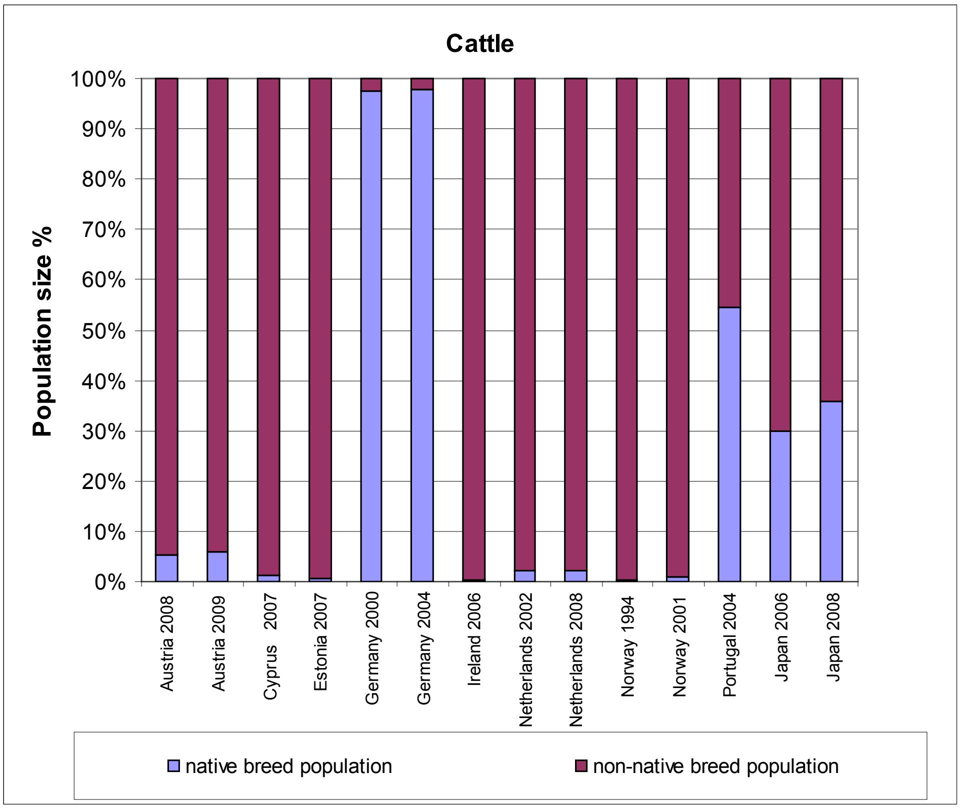

Figure 1 SEBI indicator calculated for a number of countries based on DAD-IS (accessed October 2010).

2.4 Conclusion

Although the process of collecting data developed positively, (see FAO, 2011b), both concerning number of breeds and quality of data, it appeared by far not sufficient for calculating the SEBI indicator on a worldwide scale based on DAD-IS. Moreover, for calculating the indicator a native/non-native classification is needed, which is currently not available in DAD-IS. Subsequently, it can be concluded that for producing a global agrobiodiversity map based on this indicator with data from the DAD-IS database will not be easy in the near future.

There are considerable constraints in data availability for which the SEBI indicator is sensitive. This indicator considers all breeds of a species per country and needs population data on breeding females of each breed, not only the native ones but also the non-natives. Interrogating the database showed us that this is not yet feasible. In most countries, the number of breeding females are not recorded at all, let alone regular updated. Records on native breeds, sometimes given from a conservation point of view, are not sufficient for calculating homogenization.

The SEBI indicator could be calculated for cattle in only 9 countries, mainly restricted to Europe. However this result is not specific for cattle, as for the total of all species the percentage of national breed populations with population data is around 50% (FAO, 2011b). Also for the near future it is unrealistic to expect that countries will make much progress with reporting population data. For instance, national databases do not exist for the majority of countries. To improve data collection FAO developed draft guidelines on surveying and monitoring of animal genetic resources (FAO, 2011a). Especially for developing countries breed inventories and reporting on population sizes will be a challenge.

FAO recognizes the gaps in the DAD-IS database for calculating meaningful indicators for status and trends in livestock genetic diversity. Options for an indicator of trends in genetic diversity of domesticated animals were discussed at an expert meeting organized by FAO in February 2010 (FAO, 2010a). At this meeting also a presentation was given by CGN on 'Options for indicators of genetic diversity in livestock species'. The workshop aimed at developing recommendations for livestock diversity indicators. Two important recommendations made during the workshop are also highly relevant for this project.

Firstly, breed population updates in DAD-IS are currently too incomplete to allow effective description of status or monitoring of trends and additional efforts to improve reporting are required. Secondly, it was recognized that a system for classifying breeds as "native" and "non-native" should be developed and implemented in DAD-IS (FAO, 2010a). The local vs. trans boundary breed distribution classification system was not developed as a means of classifying breeds according to their contribution to genetic diversity. In this database local means that a breed is recorded in only one country, while trans boundary breeds means that they appear in more than one country. So there is a difference is interpretation between local in the DAD-IS database and local breeds as such that they are adapted to local conditions and represent the native genetic diversity.

In order to use a native vs. non-native classification in DAD-IS and to make comparisons across countries the definition of native should be harmonized throughout the world. Currently there is no such commonly accepted definition of native and non-native. The FAO worked on this and the topic was recently discussed during the 6th session of the Intergovernmental Technical Working Group on Animal Genetic Resources for Food and Agriculture (FAO, 2010b). However, theoretical and political difficulties are the reasons that no agreement is reached on a definition of native and non-native so far.

3 Fuzzy Cognitive Mapping approach

3.1 Brief description of FCM method

Fuzzy cognitive mapping is a tool to create a conceptual model based on people's or expert's knowledge. Fuzzy cognitive maps are a form of cognitive maps, first introduced by Axelrod (1976). A Fuzzy Cognitive Map is a graphical representation of a system consisting of concepts (C_1, C_2, … C_n) and connections between the concepts. The concepts represent variables, drivers/constraints that are considered important within the system. These variables can be physical quantities that can be measured, such as amount of precipitation or percent vegetation cover or complex aggregate and abstract ideas, such as political forces (Özesmi and Özesmi, 2004). The connections represent the causal relationships between the concepts. It is called a cognitive map as it shows relationships among variables that are described by people, so it represents the perception of people on the system or problem. The maps are combined with fuzzy logic, by giving the concepts fuzzy values (between 0 and 1) to indicate the state of a concepts and the connections between the concepts a fuzzy value (between -1 and 1) to express the type of influence between the concepts (Kosko, 1986). The weight of a connection can be either positive or negative. In case of a positive relationship an increase of the value of one concept leads to an increase in the value of the other concept or a decrease of the value of one concept leads to a decrease in the value of another concept. In case of a negative relationship one concept increases as the other decreases or vice versa. For example, if a weight of a relationship between two concepts is set to ±0.9, this means that an increase in one concept will result in an almost equally strong increase of the other concept.

Besides the graphical representation, a second aspect of the FCM is the ability to show dynamic behaviour over time, by treating the Fuzzy Cognitive Map as a mathematical model. This model consists of a state vector A, which includes the values of all concepts and a vector matrix E which contains the values of all relationships between concepts. For the next state all concepts can subsequently be calculated by multiplying the previous state vector by the matrix (A x E). This calculation can be repeated as often as desired. After a large number of iterations (at least twice the number of concepts) a new equilibrium can be reached. The values of the concepts after the last iteration can only be interpreted in relative terms as it only shows that one concept becomes larger or smaller than another concept; or that a value is higher/lower than in a previous iteration step. There are four possible patterns: all concepts converge to zero, explode (values increase/decrease continuously), cyclically stabilize or that concepts stabilize at a constant value (Kok, 2009). For a more detailed description of fuzzy cognitive mapping and its application in environmental and ecological research see also Özesmi and Özesmi (2004) and Kok (2009).

3.2 Workshop setting and method

In our study the FCM approach was mainly used to analyse how experts perceive the agrobiodiversity system and to identify the most important drivers/components of this system. The tool was used in a participatory workshop setting. During the workshop a group of experts was asked to identify key factors that drive changes in agrobiodiversity in livestock. As agrobiodiversity in livestock is broad and different factors may have different impacts in different livestock species the focus during the workshop was on cattle. The basic question was: 'what threatens agrobiodiversity of cattle worldwide?' The aim of the workshop was to create a FCM that describes the agrobiodiversity system as accurate as possible, therefore participants with different backgrounds and expertise (livestock research, breeding, gene conservation, tropical husbandry, agriculture) were invited. When interpreting the FCM one should bear in mind that the FCM will be a reflection of the perceptions of the participants and might not necessarily represent the real situation. Additionally, in the FCM all relationships are assumed to be linear, which is certainly not true for many of them. The workshop was facilitated by Kasper Kok (Land Dynamics group, Wageningen UR).

For the development of the FCM the following steps were completed:
1. Description of a number of factors that are important for change in agrobiodiversity. In a brainstorming session the participants were asked to write down individually the most important factors driving agrobiodiversity. Subsequently similar issues were clustered into 10 – 15 clusters (concepts) by the whole group.
2. Discussion of the importance of these concepts and definition of relationships between concepts.
3. Definition of the type of relationship (positive or negative). In this step it was discussed how these concepts affect each other and feedback mechanisms were identified.
4. Determination of the strength of the relationships between the concepts (assign value between 0 and 1).
5. Discussion of results (FCM) and the analysis of dynamic output.

Due to lack of time the last two steps were done after the workshop by email.

3.3 Results FCM

3.3.1 Identified concepts

For understanding the FCM it is important to be sure that the concepts (drivers/issues of importance in this system) identified during the workshop are described clearly, so there are no differences in interpretation of the concepts. Here the concepts are described in more detail based on the issues mentioned by the participants and their discussions during the workshop. The concepts represent direct or indirect drivers/constraints of loss of agrobiodiversity of cattle. In total 22 concepts were identified by the participants.

C0 Agrobiodiversity of cattle
Here the focus is on intraspecific diversity in cattle worldwide. It includes the level of intraspecific diversity that still exists and is measured as the different numbers of breeds with different abundances including the diversity within and between breeds. This intraspecific diversity in cattle worldwide is the result of different livestock keepers managing cattle in different environments/ecosystems and breeding cattle populations for their specific goals (local environmental conditions, different production systems, farmers' preferences).

C1 Consumer awareness and preferences
This concept includes drivers related to consumer awareness and consumer preferences. Consumer awareness is the degree to which people take sustainable criteria (such as environmental, social or ethical factors) into account when consuming food. There is a trend for growing consumer concerns about the quality of food and the origin and production of food which may result in a shift in demand for higher-quality food or local traditional products (for example 'slow food'). It may also help consumer organizations to enforce quality standards and certification schemes. Besides consumer awareness taste and preferences of consumers are seen as important drivers that affect the demand for meat and milk. Consumer habits are influenced by a number of factors (cultural, religious, access to natural resources)

and can have significant effect on consumption of animal products locally. Examples of consumer preferences are fish consumption in Japan, vegetarianism in India, lactose-intolerance in East Asia.

C2 Quantitative demand

Quantitative demand is the amount of consumption of animal products (such as meat, milk). FAO data (FAOSTAT) show that consumption of demand for milk and meat is rapidly growing, mainly in developing countries. In developed countries demand is expected to stagnate and for meat maybe even to decline.

C3 Qualitative demand

Besides quantitative changes in demand, qualitative changes in diet are seen as important drivers. Qualitative changes in demand include changes in food patterns when consumers require a more varied menu with higher-grade food products or demand for niche market products (cheese, products of local breeds). Dietary changes are driven by urbanization and income rise, advertisement campaigns.

C4 Veterinary policy

Veterinary policy includes national or international policies (such as EU veterinary regulations) regarding prevention and control of animal diseases. This may include regulations towards emergency measures in case of disease outbreaks, vaccination programs, food hygiene, traceability of livestock products and use of veterinary pharmaceuticals. Various recent examples of disease epidemics show that veterinary measures may sometimes be in conflict with the objective of conserving agrobiodiversity. On the other hand they may also help protect animal genetic resources from dangerous epidemics.

C5 Identity producer

Farmers or livestock keeper's communities have several motives to hold particular breeds which are related to their identity. Their motives can be cultural, such as the appreciation of cultural heritage, religious or can be inspired by traditional practices. Especially in developing countries farmers attach other values to livestock than only an income. Here traditional cattle breeds fulfil other functions, such as ritual or religious needs, savings bank, insurance against droughts, providers of energy, risk-management. The breeds that are held by farmers and communities are a reflection of the cultural identity and traditions of the community that developed them but also a result of the extent of exchange between communities (concerning exchange of local knowledge, breeding material).

C6 Organization of breeding sector

This concept encompasses the level of organization of the animal breeding sector. The level of organization may differ strongly between countries. In general it seems that when animal breeders are well-organized, this benefits the genetic improvement of animal genetic resources. There are several aspects that determine the level of organization of the breeding sector such as the existence of structured breeding programs, concentration of the breeding industry and existence of breeding associations. The existence of well-structured breeding programs is regarded as positive for agrobiodiversity as it avoids indiscriminate use of exotic material in cross breeding or uncontrolled breeding, which is often detrimental for local breeds or genetic diversity in general. Today's breeders are mainly focused on productivity as their programs are market and economy driven resulting in marketing of highly productive breeding material in many different environments. Breeding of cattle can be done in a decentralized way (by 'local breeders') or can be more central organized. In general, local breeders pay attention to other objectives, such as breeding for a wide range of environments or marginal conditions (heat/drought stress). Investments in breeding and whether breeding programs are supported by national governments may differ significantly between countries, which may also influence the scope of the breeding activities. Concentration of the breeding industry is continuing, also within cattle breeding. Reduction of the number of breeding companies, which operate more international does influence the breeding programs and is presumably negative for agrobiodiversity. Another aspect is the impact of AI on breeding programs (increase of selection intensity, use of low number of sires, easy dissemination of genetic material) and hence on the genetic diversity. Finally, the existence of breeding associations may affect the organization of the breeding sector, as they have an important role in maintaining breeds (keeping herd books).

C7 Technology

Technological development is an important driver of change in the livestock sector. Technological developments in agricultural production are aimed at controlling the production environment en/or enhancing the agricultural productivity. Technological development has its impact on different parts of the livestock sector such as the production environment, breeding, infrastructures, communication or food processing. Here we mainly consider technological innovations and R&D related to breeding and agricultural production. Important technological developments are advances made in reproductive technology, including AI and ET, which have large impacts on genetic improvement programs. Especially in cattle AI is widely used in breeding programs and for dissemination of improved genetics on a large scale. In general implementation of reproductive technologies is capital intensive. Use of these reproductive technologies results in increased genetic improvement and dissemination of improved genetic material, however they often also have a narrowing effect on the genetic variation in breeds.

C8 Intensification / specialization

This concept includes the trend within the livestock productions sector for shifting from less intensive, subsistence production systems to intensive, commercial oriented systems. This intensification of livestock production systems and its increased productivity is driven by the increased demand for livestock products, changing consumption patterns and globalization of markets. Intensive production systems heavily depend on high levels of inputs (feed, chemicals and capital), technical improvements in breeding and management practices, animal health. Especially, feed efficiency and feeding management (e.g. zero grazing) have improved over the past decades. The pressure towards intensification of livestock production, here of cattle, is seen as a major threat for agrobiodiversity. This concept also includes specialization. Intensification goes together with scaling up of the production and with specialization in a single product at the farm level. As a result multipurpose breeds will no longer be used for their original functions (draught power, manure, meat and milk, skin) and are outcompeted by a few high-output specialized breeds.

C9 Environmental risks

This is a group of drivers related to environmental risks for livestock production. Here we consider mainly environmental risks related to environmental problems, climate, suitability of environment for global breeds and environmental heterogeneity (such as slope, mountainous area). However, the latter is more a state than a risk. The hypothesis is that variation in environmental factors and their associated risks can result in higher genetic diversity due to local adaptation. Locally adapted breeds in general possess valuable traits such as adaptation to harsh conditions, resistance to diseases, tolerance to drought and poor quality feed. Technological developments may reduce the environmental risks such as feed improvement, disease control, decoupling the production environment from the natural environment. On the other hand, environmental risks could also have a negative effect on native breeds and their production systems e.g. epidemics as described in C10 or droughts.

C10 Epidemics
This concept includes epidemic animal diseases. Like other disasters, epidemic animal diseases have an impact on the livestock production and its genetic diversity. In particular local breeds may be threatened by such disasters.

C11 Farmer's knowledge
Here the farmer's knowledge regarding cattle husbandry is meant. The farmer's knowledge is influenced by its educational level and access to information via extension programs, training, veterinary services etc. In general it is thought that when farmers are higher educated and have better excess to information or technological innovation, this effects their production management, access to markets and animal health control in a positive way, which subsequently leads to a change in the production system. The description mainly refers to knowledge coming from outside and not to "local" or "indigenous" knowledge.

C12 Infrastructure
This concept includes the quality of the infrastructure including transportation and communication facilities that allow the functioning of these markets. It is hypothesized that it improves access to input markets, technologies as well to output markets.

C13 Conservation policy
Here the implementation of government policy regarding conservation and genetic diversity of animal breeds, in particular cattle, is considered. Examples of policies are policies to stimulate the recognition of bio cultural heritage, subsidies for conservation (*in vivo* or *in vitro*) of rare breeds or to stimulate the use of local breeds in nature and landscape management. Also breeding policies to restrict the extent of inbreeding, so that genetic variation is maintained in breeds are part of these government policies aimed at conservation of genetic resources.

C14 Population growth
This concept includes demographic factors such as population size, population growth, urbanization, and aging of the population. Population growth is a major factor determining the increase in food demand and has effect on available natural resources, while urbanization and aging can lead to structural changes in food consumption patterns. Here mainly population growth is regarded.

C15 Extent of market integration
Extent of market integration is seen as the extent to which farmers participate in the market (self-subsistence versus market-oriented) and includes access to local, regional as well as global markets. Through globalization and liberalization of international trade farmers can easily participate in the growing world agricultural market. This especially applies for developing countries. This also asks for more uniformity in production systems and specialization for specific products. On the other hand better access to (local) markets can lead to more product diversification. In general, market integration is facilitated by infrastructure.

C17 Income farmer
Income of the farmer, which is generated if a surplus is produced for the market. In potential, enhancing the production through specialization or intensification lead to an income rise for farmers. On the other hand keeping local adapted breeds and maintaining genetic diversity may positively affect the income security for farmers in the long run.

C18 Policy support

This concept includes all kind of policy support such as government policies and legal frameworks that directly or indirectly influence the livestock sector. Policies can be positive or negative for maintaining genetic diversity. Here policy regulations are considered that in general promote economic and agricultural development, thus have a positive effect on technological innovation, production and genetic improvement within the livestock sector. Examples of policy measures are: production-oriented policies, such as preferential investment measures for export and development of large-scale production; measures to promote the marketing of global and exotic breeds; measures to promote export of animal products through subsidies on livestock services, such as AI or subsidies on milk and meat prices.

C19 Knowledge system

This concept encompass the knowledge system in relation to the livestock sector within a country and includes the functioning of research, education and extension services and the role of the government in this. There are a number of aspects that characterize the knowledge system and tell something about its well or bad functioning. Some examples are: the role of the government in managing/controlling and financing research and education, the level of investments in research and the funding structure (private, public, international), the way extension is coordinated, financed and organized (private, public). The knowledge system directly influence the knowledge level of the farmer, e.g. through the influence of extension, functioning of veterinary services or the level and accessibility of agriculture education.

C20 Income consumer

Consumer's income can be represented by gross domestic product (GDP) per capita or by GDP at its purchasing power parity (PPP). As consumer incomes rise, their demand for food increases, but also their demand for a higher quality. Thus the level of per capita income is seen as an important determinant of the composition of food expenditure.

C21 Availability of natural resources

Access to natural resources include access to land and water, for instance livestock keeper's rights in relation to access to grazing land and water resources, or energy and biological resources. As human populations grow, more pressure is being placed on natural resources to provide food. This may lead to soil degradation, habitat destruction, overgrazing, and salinization. Availability of limited resources also forces to specialization and increased use of technology and more efficient use of resources in livestock production.

C22 Vertical / horizontal integration

The increasing horizontal concentration and vertical integration of the food chain is an important driver of change in the livestock sector. Especially, the dairy sector in some countries has a high degree of vertical integration. Changing consumption pattern towards high-value products, more technological innovations and more attention for food safety and convenience result in higher integration and responsibility along the food chain.

3.3.2 Interpretation of FCM

The graphical representation of the FCM for cattle agrobiodiversity which is produced by the expert group is shown in Figure 2. The boxes represent the concepts of the system, the weighted arrows the relationships between them. All values in the graph should be interpreted in relative terms.

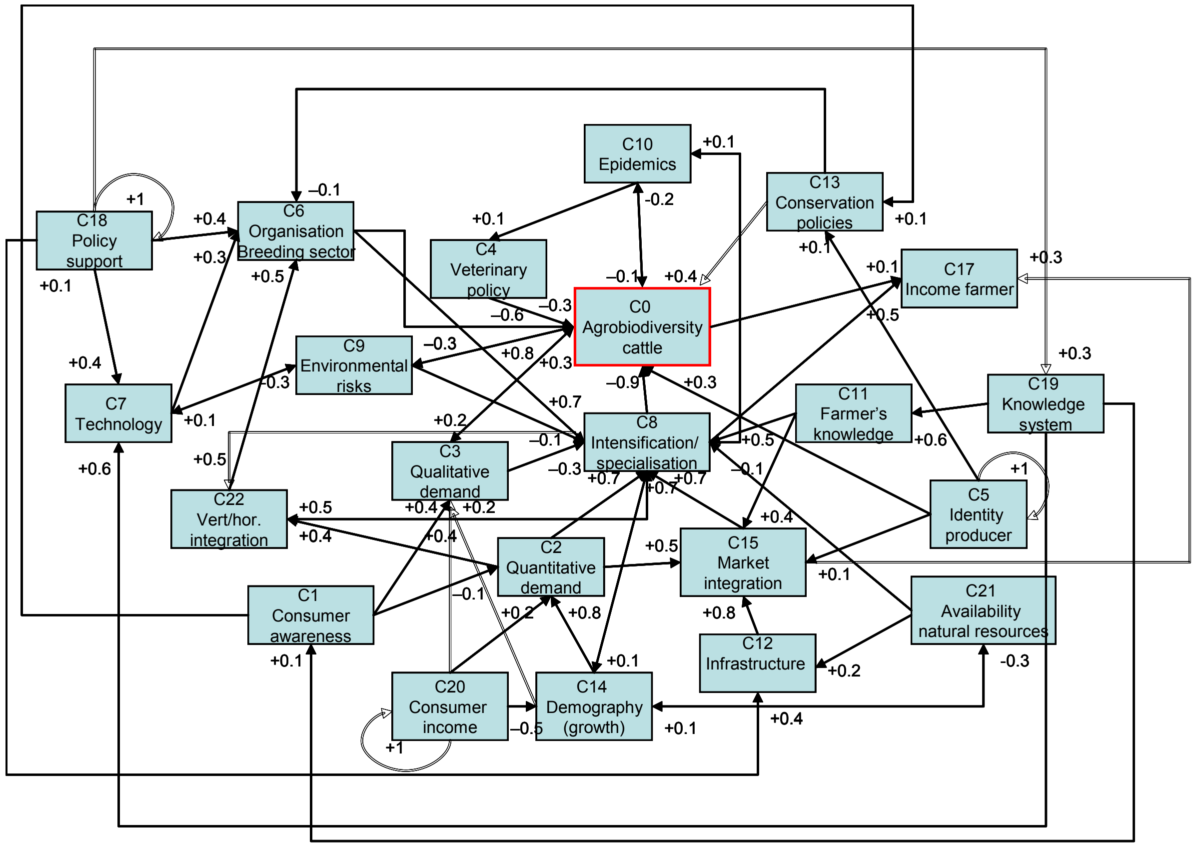

Figure 2 Fuzzy Cognitive Map of agrobiodiversity in cattle worldwide.

The created FCM consists of 22 concepts that have many positive and negative connections. Having such a large number of concepts in a map makes the map more complex and consequently more difficult to analyse. The workshop participants assumed that identity producer (C5), policy support (C18) and consumer income (C20) are external drivers. In the FCM these concepts have only out coming arrows. These factors influence the system from outside and are not influenced by factors described in the FCM. In the FCM they drive themselves (+1). Income farmer (C17) is the only concept that does not affect the system, as it has no out coming arrows.

Interpretation of the FCM leads to the following insights:

- A central factor in the FCM of agrobiodiversity is intensification/ specialization. It has many in coming and out coming arrows with high values. The relationship between agrobiodiversity and specialization/intensification is considered as most important by the workshop participants as it has the strongest link. A high pressure of specialization/ intensification (- 0.9) results in a very low level of agrobiodiversity.
- Intensification/ specialisation (C8) is influenced by several others: extent of market integration (+0.7), quantitative demand (+0.7), vert/hor. integration (+0.7), organisation of breeding sector (+0.7). Demand for agricultural products is an important driver for intensification/ specialization. Increasing production and specialisation and changing production systems towards a more commercial orientation are expected when demand is rising. The major driving factors behind increasing demand for animal products are population growth and income growth.

- Other strong relationships in the FCM are infrastructure and extent of market integration (+0.8), demography and quantitative demand (+ 0.8) and environmental risks and agrobiodiversity (+0.8). (see also Table 2). For instance intensification/ specialisation is highly facilitated by access to markets for inputs, outputs, genetic material or access to technologies, which itself is dependent on the quality of the infrastructure.
- Another important factor in the system is policy support (C18). It stimulates intensification/ specialisation and has a strong negative impact on agrobiodiversity via several relationships. The impact of policy support on intensification through its influence on the organization of the breeding sector (C6) appears to play an important role here. Both the length of this link (C18→C6→C8) as well the strength of this indirect link (C18 → C6 → C8 = 0.4 x 0.7 = 0.28) support this.
- The relationship between consumer income (C20) and demography (C14) is a difficult one. As demography was not clearly defined in our system, it can have different interpretations. It seems that in this system demography is mainly interpreted as population growth as it is assumed that consumer income has a strong inhibitory effect on demography (C20 → C14 = -0.5). However, in reality demography includes other aspects such as urbanisation and ageing. So if urbanisation is also included in demography, the influence of consumer income on demography might be less strong. As said before, it would have been better to split demography in population growth and urbanization in order to provide a better description of the relationship between income and the different aspects of demography.

A number of factors were described in a very general way and not discussed in detail during the workshop such as demography and policy support. A disadvantage of such a general description is that the factor can be explained in several ways by the experts. Demography was described in a general way. Actually it would have been better to split demography up in population growth, urbanization and ageing in order to provide more detail. Though, this would again have resulted in a more complex map. The same applies for policy support, which can include various policies with different effects. In this system mainly policy support activities such as active marketing of global breeds, poor national policies, subsidy on meat and milk were considered which in generally have a positive impact on the organization of the breeding sector and negative effect on agricultural biodiversity.

Some of the described relationships could have a positive or negative sign. An example of this is the relationship between producer identity and the extent of market integration. In this FCM, it is assumed that farmers that have commercial motives will in general look for opportunities for access to markets. If this is the case the link is rather low but positive (+ 0.1). On the other hand traditions may have an inhibitory effect on market access.

3.3.3 Dynamic analysis

Besides the graphical presentation of the FCM it is possible to analyse the dynamic behaviour of the system or in other words to analyse how the concepts interact with each other. In Figure 3 a presentation of the dynamic outcome of the system after the 45 iterations is given. The figure shows that the system reaches a steady state rather quickly. After 10 iterations the values of all concepts have stabilized. From the steady state calculation it can be seen what the importance of the concepts is in relationship to each other in the created FCM. As said before the values in the end situation cannot be interpreted in absolute terms, but tell us that some concepts are relatively higher than others. Figure 3 shows that in the steady state situation a high value of intensification/ specialisation (C8) is reached which drives loss of agrobiodiversity. In this situation intensification/ specialisation has gone up on the expense of agrobiodiversity (C0). Also organisation of the breeding sector (C6), income farmer (C17) and vertical/horizontal integration (C22), technology (C7), market integration (C15) have gone up.

Additionally, dynamic analyses can be performed to investigate how the system reacts if some factors or relationships are changing. The outcome of such simulations can help us to understand how the system could behave when some factors have changed. For instance to answer the question 'what are influential factors and low-impact factors in this system?' an external check was done. This was done by adding a new external factor to the FCM ($C_{16} \rightarrow C_n$ =1.0 or -1.0). A factor was stimulated (+1.0) or given a pressure (-1.0) and new matrix calculations were performed to determine what the state of the system will do and in particular to determine what effect this has on agrobiodiversity. These dynamic analyses resulted in the following interpretations:

- The external check showed that the system is particularly sensitive to C2 (quantitative demand), C6 (organisation of the breeding sector), C8 (intensification/ specialisation), C11 (farmer's knowledge), C12 (infrastructure), C14 (demography), C15 (extent of market integration), C18 (policy support), C19 (knowledge system) and C22 (vert / hor. integration). If one of these factors is stimulated (increased demand for agricultural products, better organization of the breeding sector, more intensification of production system, increased farmer's knowledge, better infrastructure, more population growth, increased market integration, increased influence of policy, increased knowledge system or higher vert/hort. integration) this leads to a lower agrobiodiversity compared to the original situation, although the system remains stable. A pressure on one of these factors results in tilting of the system. For example, when quantitative demand (C2) is strongly decreased this stimulates agrobiodiversity. After about 10 iterations the system stabilizes with an increased, positive value for agrobiodiversity and a low negative value for intensification / specialization.
- Low-impact factors in this system are C1 (consumer awareness), C3 (qualitative demand), C4 (veterinary policy), C5 (identity producer), C7 (technology), C9 (environmental risks), C10 (epidemics), C13 (conservation policies), C17 (farmer income), C20 (consumer income), C21 (availability of natural resources). The system is rather insensitive for changes in any of these factors. Altering one of these variables has little effect on the level of agrobiodiversity compared to the original situation.
- When population growth (C14) is strongly reduced in this system, this leads to an increase in agrobiodiversity and less intensification, mainly through its effect on reducing demand (tilting of the system).
- Surprisingly, the influence of income (C20) on demand is less strong in this system. A negative or positive boost to income has little effect on the system, even little influence on demand (C2). It is questionable if this simulated situation presents the reality correctly. According to literature, purchasing power and demographics (especially urbanization) are the two main driving forces for increased consumption (demand) of animal products (milk and meat), of which purchasing power is seen as the most influential. In other words, consumption of animal products increases with purchasing power. FAO data show that there is a strong positive effect of income growth on the consumption of animal products at low-income levels, but rather a low or even negative effect at high-income levels. Demography (particularly urbanization) is the second most important factor that affects consumption of animal products, regardless of income level. As noted earlier, more boxes are required in order to properly address this aspect in the FCM (population growth and urbanization as different aspects of demography).
- The system appears very sensitive to policy support (C18). Small changes in policy support can easily get the system out of balance.

Table 2 Relationships identified in the FCM and their values.

Relationship						Sign	Value
C8	→	C0	Intensification/specialization	→	Agrobiodiversity	-	0.9
C12	→	C15	Infrastructure	→	Extent of market integration	+	0.8
C14	→	C2	Demography	→	Quantitative demand	+	0.8
C9	→	C0	Environmental risks	→	Agrobiodiversity	+	0.8
C15	→	C8	Extent of market integration	→	Intensification/specialization	+	0.7
C2	→	C8	Quantitative demand	→	Intensification/specialization	+	0.7
C22	→	C8	Vert/hor. integration	→	Intensification/specialization	+	0.7
C6	→	C8	Organisation breeding sector	→	Intensification/specialization	+	0.7
C19	→	C11	Knowledge system	→	Farmer's knowledge	+	0.6
C19	→	C7	Knowledge system	→	Technology	+	0.6
C6	→	C0	Organisation breeding sector	→	Agrobiodiversity	-	0.6
C11	→	C8	Farmer's knowledge	→	Intensification/specialization	+	0.5
C2	→	C15	Quantitative demand	→	Extent of market integration	+	0.5
C20	→	C14	Income consumer	→	Demography	-	0.5
C22	→	C6	Vert/hor integration	→	Organisation breeding sector	+	0.5
C8	→	C17	Intensification/specialization	→	Income farmer	+	0.5
C8	→	C22	Intensification/specialization	→	Vert/hor integration	+	0.5
C1	→	C3	Consumer awareness	→	Qualitative demand	+	0.4
C11	→	C15	Farmer's knowledge	→	Extent of market integration	+	0.4
C13	→	C0	Conservation policies	→	Agrobiodiversity	+	0.4
C18	→	C12	Policy support	→	Infrastructure	+	0.4
C18	→	C6	Policy support	→	Organisation breeding sector	+	0.4
C18	→	C7	Policy support	→	Technology	+	0.4
C2	→	C22	Quantitative demand	→	Vert/hor integration	+	0.4
C20	→	C3	Income consumer	→	Qualitative demand	+	0.4
C0	→	C9	Agrobiodiversity	→	Environmental risks	-	0.3
C14	→	C21	Demography	→	Natural resources	-	0.3
C15	→	C17	Extent of market integration	→	Income farmer	+	0.3
C18	→	C19	Policy support	→	Knowledge system	+	0.3
C3	→	C0	Qualitative demand	→	Agrobiodiversity	+	0.3
C3	→	C8	Qualitative demand	→	intensification/specialization	-	0.3
C4	→	C0	Veterinary policy	→	Agrobiodiversity	-	0.3
C5	→	C0	Identity producer	→	Agrobiodiversity	+	0.3
C7	→	C6	Technology	→	Organisation breeding sector	+	0.3
C7	→	C9	Technology	→	Environmental risks	-	0.3
C0	→	C10	Agrobiodiversity	→	Epidemics	-	0.2
C0	→	C3	Agrobiodiversity	→	Qualitative demand	+	0.2
C14	→	C3	Demography	→	Qualitative demand	+	0.2
C20	→	C2	Income consumer	→	Quantitative demand	+	0.2
C21	→	C12	Natural resources	→	Infrastructure	+	0.2
C0	→	C17	Agrobiodiversity	→	Income farmer	+	0.1
C1	→	C13	Consumer awareness	→	Conservation policies	+	0.1
C1	→	C2	Consumer awareness	→	Quantitative demand	-	0.1
C10	→	C0	Epidemics	→	Agrobiodiversity	-	0.1
C10	→	C4	Epidemics	→	Veterinary policy	+	0.1
C13	→	C6	Conservation policies	→	Organisation breeding sector	-	0.1

Relationship						Sign	Value
C19	→	C1	Knowledge system	→	Consumer awareness	+	0.1
C21	→	C14	Natural resources	→	Demography	+	0.1
C21	→	C8	Natural resources	→	intensification/specialization	-	0.1
C5	→	C13	Identity producer	→	Conservation policies	+	0.1
C5	→	C15	Identity producer	→	extent of market integration	+	0.1
C8	→	C10	Intensification/specialization	→	Epidemics	+	0.1
C8	→	C14	Intensification/specialization	→	Demography	+	0.1
C9	→	C7	Environmental risks	→	Technology	+	0.1
C9	→	C8	Environmental risks	→	Intensification/specialization	-	0.1

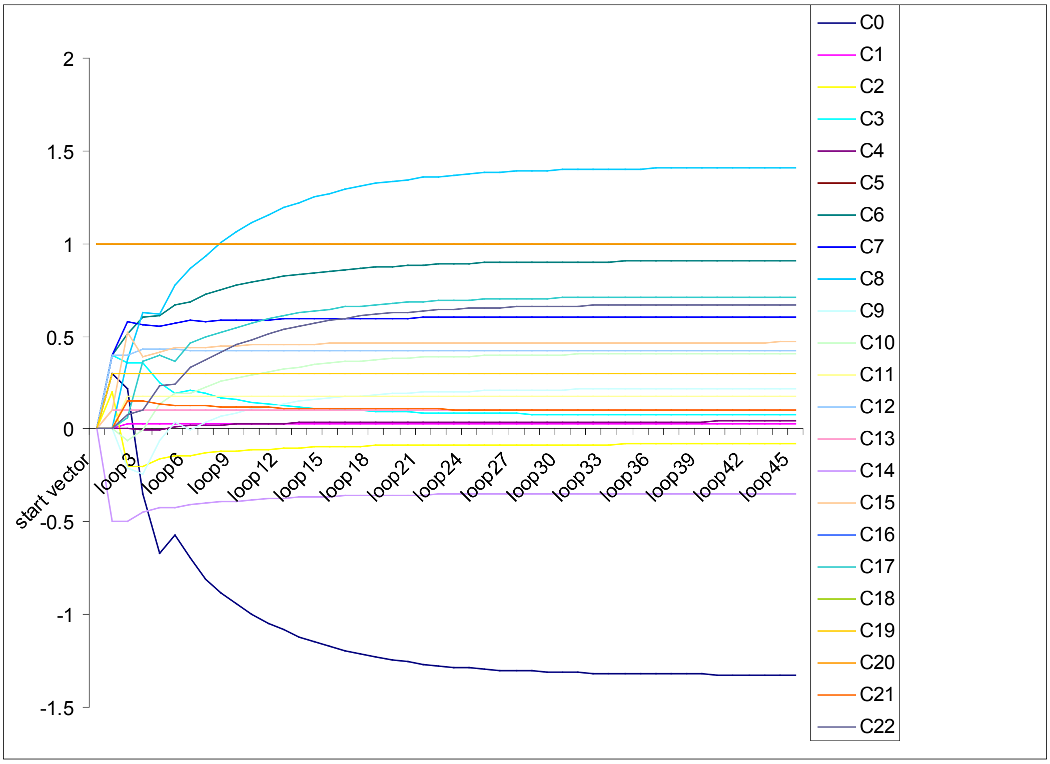

Figure 3 Dynamic output of Fuzzy Cognitive Map in the current situation, showing the values of concepts for the first 45 iterations. Initial state vectors of C5, C18 and C20 were set to 1, all others were 0. X-axis: number of iteration steps; Y-axis; value of concepts.

3.4 Discussion

The FCM is a semi-quantitative model, based on the understanding of experts of how the system works, and can be seen as a first step in developing a prototype of an agrobiodiversity model. The FCM approach was especially valuable for us for understanding the system better. However, it may not always represent the reality as it is based on a number of assumptions. For instance, inherent to the method all relationships in the FCM are assumed to be linear, which is certainly not true for many of them. For example the relationship between intensification/ economies of scale and disease outbreaks or the influence of consumer income (GDP per capita) on population growth. These individual relationships should be scientifically improved and underpinned by systematic literature search. Another example is the time scale. It has been assumed that there is no time relationship in the changes of the concepts values. The values of concepts change within the same time unit (here an iteration). In reality the processes described in the system do not always act at the same time scale. These assumptions may have consequences for the results and adequacy of the model. For an extensive discussion on strong and weak points of the FCM method, please see also Kok (2009).

Furthermore some comments can be made on the created FCM. For instance the created FCM cannot be generally applied for agrobiodiversity. It was created for livestock diversity with a focus on cattle and cannot be straight transferred to other types of diversity (crops or aquatic biodiversity).

The FCM is built on the views of various experts participating in the workshop. We are aware that the view of the participants that created the FCM might therefore be one-sided and that a rather 'Western view' might be given on the problem. For instance, farmers knowledge is regarded as knowledge coming from outside such as education. Here informal (indigenous) knowledge is not taken into account or considered as less important, which is very questionable especially for developing countries. Also the weighting of the relationships between factors might be location-dependent. So the question remains how specific or generic is the FCM that is created. Therefore it is recommendable to repeat such a FCM exercise with different and larger groups (involving people from different regions/countries and with different expertise/background).

Some omissions or assumptions were made during the FCM creation which may not be correct afterwards. For instance one can argue that some concepts or relationships are missing. For example, a concept that could be added to the FCM is the availability of alternative employment that may attract people away from livestock keeping. A number of factors were assumed to be external drivers. However, one of them 'identity producer' is likely to be affected by some of the other factors within the system: traditions may be affected by education or by infrastructure; use of animals for 'energy' may be affected by the availability of alternative technology. Another example is that farmers income does not affect the system as it has no out coming arrow in the FCM. It is, however, assumable that the income of the farmer determines the possibilities to make investments and to access knowledge. Yet it can be assumed that those relationships that were perceived as the most important ones were included and that the absence of relationships is an indication of its relative minor importance.

Summarizing, the suitability of the created FCM needs to be assessed and cannot directly be used as a model. Therefore conclusions should be drawn carefully based on the outcome of the FCM analysis. Some tentative conclusions are that the experts regarded intensification/ specialisation as the strongest driver of agrobiodiversity loss. If intensification/ specialisation is increased agrobiodiversity will decrease. Other key factors in this system seem to be quantitative demand, organisation of the breeding sector, farmer's knowledge, infrastructure, demography, extent of market integration, policy support, knowledge system and vert / hor. integration. The system proved to be especially sensitive for these factors. To see if these outcomes fit the real situation needs to be validated.

Definitely this FCM needs improvement. Though the FCM approach and the simulations of alternative developments were very valuable as they did feed the discussions and brought together the expert knowledge in an explicit way. Therefore, it improved our understanding of how a complex system as the livestock diversity system might function. This output of the FCM should be seen as a first tentative step towards identifying the key indicators for drivers of change in livestock diversity.

4 From FCM to indicators

From the FCM analysis in the previous chapter a number of drivers/factors were identified as most influential in the agrobiodiversity system: Quantitative demand, organisation of the breeding sector, intensification/specialisation, farmer's knowledge, infrastructure, demography, extent of market integration, policy support, knowledge system and vertical/horizontal integration. For these factors a set of (proxy) indicators for analysing the loss of agrobiodiversity should be developed. Below a number of potential indicators are suggested and only shortly described. In order to use these indicators for a cluster analysis to produce an 'archetype agrobiodiversity map' their potential use is also discussed (see also Table 3 for list of indicators and potential data sources). Our choice of indicators was mainly guided by the outcome of the FCM, but also by experts and earlier reports (Eaton *et. al.*, 2006, Buiteveld *et. al.*, 2009, FAO, 2010a).

Intensification/specialization

The amount of animal products produced depends on the amount of animals reared and land used, the production and management intensity. We identified three potential indicators related to intensification. A management factor, which represents the difference between the theoretically feasible yield of crops and the actual yield. For instance such management factors are used within IMAGE. IMAGE (Integrated Model to Assess the Global Environment) is a tool to assess the environmental consequences of human activities worldwide. However, they are defined regionally (24 regions) and it will be difficult to gather data on production system or farm level, what makes the potential for us low. An alternative for using the management factor at a regional level would be a spatial specific allocation of the management factor, for instance related to road density. A second indicator could be the production output factor, representing the production based on number of animal, used in IMAGE. Although, the same restrictions of regionally defined data applies here and therefore the potential for use at farming system level is low.

Moreover, intensification goes together with economies of scale. In order to achieve economies of scale farms will increase. This aspect may be indicated by farm sizes, number of farms or farmers. Farm size may capture aspects of economics of scale and intensification of the production system. The farm size can be given by the number of animals/ha. For example, the density maps produced by GLiPHA (Global Livestock Production and Health Atlas) could provide such information. However, measurability and data coverage worldwide will be medium.

Quantitative demand & demography

Purchasing power increases the demand for animal products, although very high GDP means that demand is decreasing again. Demography indicated by higher population also increases the quantitative demand. Therefore as a proxy for demand we suggest two indicators: the human population density and GDP per capita.

Organisation of breeding sector

To include indicators for the organisation of the breeding sector is rather difficult. The best option might be an indicator that represents the density of breeding organizations, such as the number of breeders that are member of a breeder's association. Breeder's organisations may be organised in different ways: e.g. per species, utilization (beef/dairy) or per breed. Though, such organisations do not exist in all countries, but only primarily in Western Europe and South America (FAO, 2007). Other relevant indicators related to the organization of the breeding sector are: application of modern breeding strategies or number of breeding goals. However, for these, data would be very difficult to obtain.

Farmer's knowledge & knowledge system
If we assume that the farmer's knowledge within a country is a reflection of the knowledge of the total human population or the knowledge system of a country, these two factors can be combined and be represented by one indicator. We could propose the education component of the Human Development Index (HDI) here. The education index (EI) measures access to knowledge and is based on two indices: mean of years of schooling for adults aged 25 years and expected years of schooling for children of school going age. A higher EI implies a better access to formal knowledge (ignoring indigenous knowledge).

Extent of market integration
Access to local, national and international markets includes access to markets for inputs (tractors, irrigation systems, fertilizers, feed etc.) and outputs (animal products), but also access to knowledge or education and technology, information technology (e.g. internet). Extent of market integration can be represented by accessibility to markets, measured as travel time to nearest urban areas/markets.

Infrastructure
Quality of the infrastructure or access to infrastructure can be represented by infrastructure density, measured as the total length of roads per square kilometre.

Policy support
Policy support might be represented by governance indicators (World Bank, OECD). For example the World Wide Governance Indicators (WGI) of World Bank capture six key dimensions of governance (voice & accountability, political stability and lack of violence, government effectiveness, regulatory quality, rule of law, and control of corruption). Good governance, considering these six aggregate indicators, is seen as a key factor for development. However governance is a rather broad concept and maybe too broad for being a meaningful indicator for policy support.

Vertical/horizontal integration
Vertical/horizontal integration might be represented by the degree of concentration within the sector, e.g. the dairy sector. However, it will be difficult to develop a meaningful indicator for which also data can be gathered.

Environmental risks
In the FCM environmental risks are not seen as most influential in changing the level of agrobiodiversity. Environmental risks can be represented by land use changes, the agro potential or the degree of heterogeneity of the environment. As said before, the environmental heterogeneity is not a risk, but actually a state. It is assumed that a varied environment (including soil, rainfall, elevation, moisture, land quality, slope, and climate) gives rise to more diversity in the livestock population. For this an indicator could be developed that indicates that a high environmental variation goes together with a high agrobiodiversity. Heterogeneity could be ranked on a scale from 1 (least heterogeneous) to 10 (most heterogeneous).

It should be noted that the FAO currently are developing a large set of maps describing the natural production environment of breeds as part of the to be launched production environment descriptors (PEDs) module in DAD-IS. In the future, analysis of these maps versus breed distribution/breed diversity may reveal some of the relationships between the production environment and livestock diversity.

Table 3 List of suggested indicators and their potential for use.

Factor	Indicator	Description	Potential for use	Data source
Intensification/ specialisation	Management factor	The difference between the theoretically feasible yield of crops and the actual yield	Low, management factors are defined for the seven aggregated food crops, four biofuel crops, grass and fodder species regionally (24 regions). Difficult to gather data on production system or farm level	IMAGE (PBL)
	Production output factor	Production based on number of animals	Low, defined regionally, no data available on production system or farm level	IMAGE (PBL)
	Farm size	Number of animals/ha	Medium, mostly on country level	GLiPHA
Quantitative demand & demography	GDP	GDP per capita	Good	World bank
	Human population density	Population per km^2	Good	Landscan (ORNL, global population project)
Organisation of breeding sector	Use of modern breeding strategies		Low, difficult to obtain data	
	Number of breeding goals		Low, difficult to obtain data	
	Concentration/ density of breeding organisations	The number of breeders that is a member of a breeding association	Medium, difficult to obtain data, no worldwide application	
Farmers knowledge & knowledge system	Education level	Education component (EI) of the Human Development Index (HDI)	Good, data at country level	UNDP
Extent of market integration	Accessibility to markets	Travel time to nearest urban areas/markets	Good	Nelson, 2008 IMAGE (WUR, PBL)
Infrastructure	Infrastructure	Road density (total length of roads per km$^{2)}$	Good	Natural Earth data or IMAGE (PBL)
Policy support	National policy on breeding	Presence or absence of policy	Low	
	Governance	Governance index based 6 indicators	Medium, too broad, data available on country level	World bank (composite data)
Vert/ hor integration	Concentration within the dairy sector		Low	
Environmental risks	Land use		Good	Several datasets: FAO, Global Land Cover 2000 (GLC, 2000)
	Environmental heterogeneity	Environmental risk factor in categories (1 to 10)	Medium	

In Figure 4 the FCM is concentrated on the most influential factors (in blue) including our first selection of indicators (represented by the green boxes).

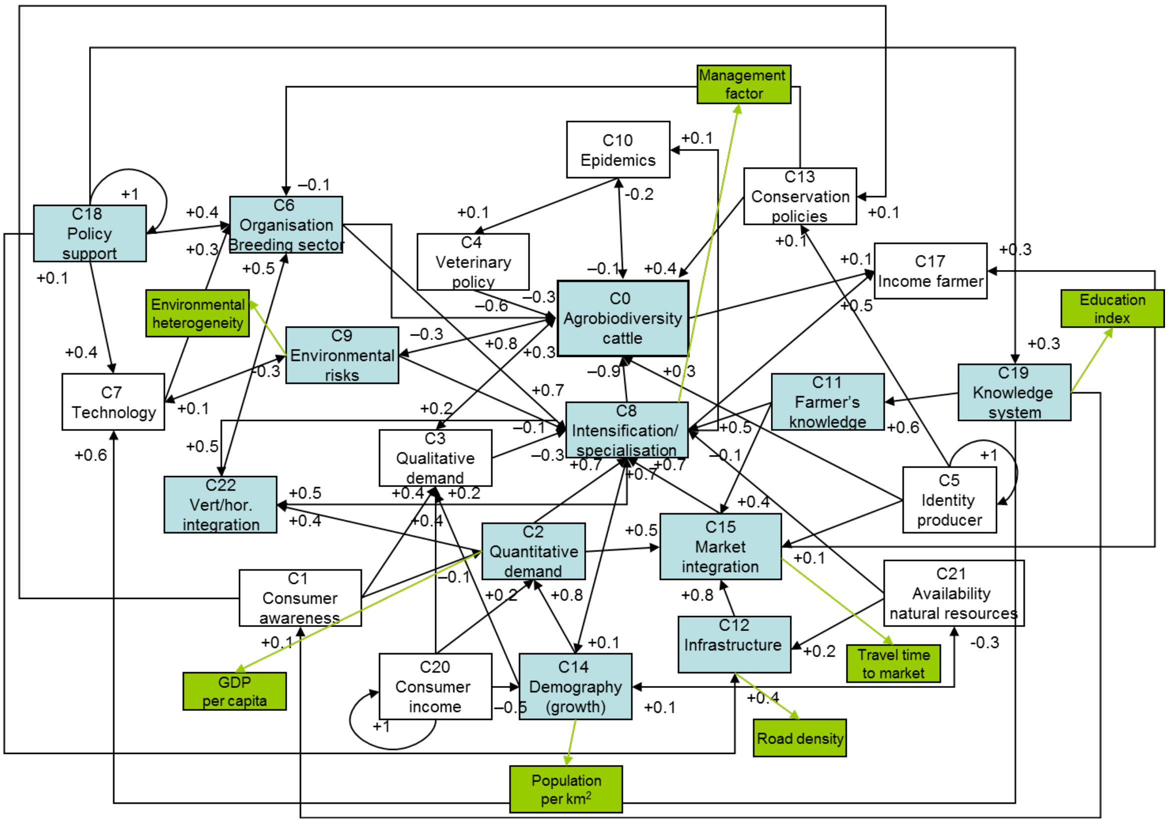

Figure 4 Adjusted FCM with first selection of indicators.

5 Concluding remarks and steps forward

The underlying study has provided new and more detailed insights in the relationships between pressures/drivers and agrobiodiversity which is needed for modelling agrobiodiversity. Below some conclusions and steps forward are summarized.

Agrobiodiversity map

One of the objectives of this study was to produce a global agrobiodiversity map based on previously proposed genetic diversity indicators. Therefore the question was asked whether sufficient good quality data is available to produce such a map. For cattle, which was chosen as a pilot species, the DAD-IS database was interrogated for calculating the SEBI indicator. Our conclusion is that the quantity (time series) as well the quality of data in the DAD-IS database is currently insufficient to allow a meaningful calculation of the indicator and to produce the agrobiodiversity map. DAD-IS is the only publicly available global database on genetic diversity in livestock and is seen as the most appropriate way to gather information on genetic diversity. Therefore it is suggested to investigate if alternative indicators could be calculated based on the currently available data in DAD-IS. The expert meeting on indicators for animal genetic resources, organized by FAO in February 2010 recommended a set of three indicators to be calculated at national, regional and global levels for livestock species (FAO, 2010a):

1. Number of native breeds;
2. Proportion of the total population accounted for by native and non-native breeds;
3. Number of breeds classified as at risk, not at risk and unknown.

Both the first and second indicator might be an appropriate alternative indicator for our objective. The first indicator can be calculated directly from existing data in DAD-IS, provided that a classification system for native and non-native is developed and implemented in DAD-IS. Therefore it is worthwhile to put effort in further work, as recommended by the expert meeting, to develop such a native/non-native classification system.

For the second indicator solutions should be investigated towards filling the gaps in the DAD-IS database needed for producing an agrobiodiversity map as no such data is available yet. The only way to get data into DAS-IS is via National Coordinators. It is not likely that these data can be obtained via DAD-IS in the near future for the majority of countries. Therefore, alternatively, it is recommended to start data collection in a number of countries by searching national databases, by more in-depth data collections based on case studies or by inventories in collaboration with national authorities. This is however a highly complex, costly and time-consuming way of gathering genetic diversity data.

Qualitative description of agrobiodiversity

The second objective of this study is to develop a better understanding of the relationship between agrobiodiversity and factors for which data are available, as a basis for modelling biodiversity. This was done by using the Fuzzy Cognitive Mapping approach applied on cattle. FCM appeared to be an interesting method to map the agrobiodiversity system. It gave us more insight in the factors leading to agrobiodiversity loss in cattle. The system described by the experts appeared to be a rather complex map with many factors (21) influencing agrobiodiversity, which made it difficult to analyse. Some factors seem to be more influential than others. For some important factors appropriate indicators or proxies were identified. Given the current data availability it appeared not to be easy to develop indicators for all relevant factors. For the factors: quantitative demand, demography, knowledge system, market access, infrastructure and environmental risks quantitative indicators are available. The challenge lies in finding appropriate and feasible indicators for intensification/ specialization, organization of the breeding sector, policy support, vert/hor. integration and environmental risks such as environmental heterogeneity.

Steps forward

It should be mentioned that this study has a highly exploratory character. Risks lie in particular in the limitations to test the FCM and data availability for state of diversity as well for drivers. It is therefore recommended to take a step wise approach when proceeding further.

The question "Is it possible with our new insight in key drivers based on the FCM analysis to construct a first 'agrobiodiversity archetype map'? remains. To follow the so-called archetype approach the next step would be to perform a cluster analysis of the most important indicators. To do this it should be assessed that the FCM and the key drivers identified in it are indeed correct and that a relevant set of indicators is selected. As noted before in the FCM a rather 'Western view' was given. However, to test the FCM, for instance in a range of diverse countries, real data are needed. For many of the drivers identified data sets are lacking or are very difficult to obtain. Without data for the state of genetic diversity and the various driving factors it will be difficult to assess this. Even if it is assumed that the right set of indicators for drivers is selected here, data availability will also remain a problem for proceeding further with a cluster analysis.

Currently the development of a suitable model for assessing agrobiodiversity might therefore be rather complicated. In further research effort should be put in data collection, which will allow us to test and optimize the FCM. For the diversity indicator a more in-depth data collection should be started. The best way to do this is to start collaboration with a number of countries. A more detailed data collection for the drivers could be done as well. Especially a better description of the production environment in relation to intensification and specialization is needed. The currently suggested indicators (drivers) of management and production factors are too broad (based on IMAGE data on regional level). As an alternative, it is worthwhile to investigate data of the production environment descriptors (PEDs) proposed in the guidelines for phenotypic characterisation produced by FAO/WAAP (2008). Relevant descriptors mentioned in these guidelines are the livestock production system, the level of confinement, climate modifiers, control of disease, management in relation to feed and water availability, and market characteristics (market orientation, type of market, niche).

This simple pilot study indicated that there are possibilities to model agrobiodiversity in general, but it takes a next step to see if there are sufficient alternative socio-economic indicators available to develop a global agrobiodiversity map. Moreover it takes time and budget to carry out the necessary case studies for validation. If these conditions can be met, it is worth to proceed further.

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