BIOLOGICAL DIVERSITY OF LIVESTOCK AND CROPS: USEFUL CLASSIFICATION AND APPROPRIATE AGRI-ENVIRONMENTAL INDICATORS

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Biological Diversity of Livestock and Crops:
Useful Classification and Appropriate Agri-Environmental Indicators

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Abstract

Compared with the OECD approach (OECD, 2001), we suggest a different and more appropriate method of classifying biological diversity for purposes of indication and monitoring. The way of indicating biological crop and livestock diversity by the OECD reveals several gaps, for which this work wants to propose some practicable solutions. Here we present a pragmatic approach to expand the OECD's set of indicators for additional issues like crop species diversity and for driving forces impacting the genetic diversity, which are not considered in the OECD work up to now. The data for the suggested indicators presented below are sufficiently available, though the indicators can be realized immediately.

Keywords

Agri-environmental indicators, biodiversity, genetic diversity, lifestock, crops, breeding

1 Introduction

On behalf of the German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety, the Institute of Organic Agriculture is working as part of a R+D-project on agri-environmental indicators, responsible for the categories biodiversity, wildlife habitats and landscape. Primarily, we are instructed to implement the OECD indicators and to put them in concrete terms (OECD, 2001). Furthermore, we shall check their suitability for national environmental reporting systems and for international reporting duties such as within the scope of the Convention on Biological Diversity (CBD). If generally appropiate, the indicators should be further developed, modified or completed.

2 Classification of Biological Diversity for Purposes of Indication and Monitoring

The CBD (1992) concerns all living organisms, distinguishing biological diversity between the genetic, species and ecosystem level (Figure 1). In contrast, the OECD proposal assigns the genetic level only to livestock and crops and the species level to wildlife fauna and flora. However, crop species diversity is at least as relevant as the diversity of varieties. Additionally, the division in biodiversity at the one hand and habitats at the other hand seems to be artificial and should be suspended (Figure 1). Therefore we propose an approach where we divide biological diversity into the three thematic domains of livestock/crops, wildlife and the aspect of non-native (alien invasive) species. Each of these domains should be captured by appropriate indicators at all levels according to the CBD which are relevant ("X" marked in Figure 1). That way, our approach is completely compatible with the CBD.

Figure 1: Biological diversity as classified within the approaches of the CBD, the OECD and compared with the approach presented here.

Convention on Biological Diversity (CBD):

Biodiversity (→ all living organisms, wild and domesticated)		
Genetic Diversity	Species Diversity	Ecosystem Diversity

OECD Agri-Environmental Indicators:

Biodiversity			**Wildlife Habitats**
Non-native Species	Genetic Diversity (→ livestock, crops)	Species Diversity (→ wildlife species)	(→ wildlife species)

Classification of agri-environmental indicators suggested in this work:

	Biodiversity		
	Genetic Diversity	Species Diversity	Ecosystem Diversity
1. Livestock and crops	X	X	(X)
2. Wildlife	X	X	X
3. Non-native species	(X)	X	-

Source: CBD, 1992; OECD, 2001; own

3 Appropriate Agri-Environmental Indicators of Livestock and Crop Biodiversity

The OECD indicators capture the number of registered livestock breeds and crop varieties, the share of key breeds/varieties and the number of endangered breeds/varieties. This reduction to a few state indicators makes the issue easily comprehensible, but it meets only partly the demands of the subject. As the number and shares of breeds and varieties capture only a part of genetic diversity, important driving forces impacting genetic diversity should be added to the set of indicators. Furthermore, crop species diversity as an essential aspect of agrobiological diversity is not considered at all in the OECD set. The number of endangered varieties is a desirable indicator, but at least in Germany up to now, endangered varieties are neither defined nor registered. That is why this indicator cannot be implemented yet. Livestock species diversity can perhaps be neglected, particularly in industrialized countries, because rare species of livestock are in most cases non-native, ‚exotic‘ species (e.g. alpaca in Germany), for whom the ‚host‘ countries see no responsibility to preserve them. Frequently, rare species are kept by non-farmers only for leisure purposes. The loss of animal genetic resources is linked closely to the extinction of domesticated animal breeds. In Germany however, due to the activity of a private initiative and more recently also due to public subsidies, the extinction of breeds over the last 150 years has ended. In the short- and medium-term, further losses of originally domestic breeds are not likely to happen. Therefore, actual changes in the number of registered breeds are based on the introduction of non-native breeds, often only for leisure purposes. For instance the case of an introduction of four female Tajikistanian goats and their registration in 1999 may increase the genetic diversity in Germany in a marginal way. However it is normally no contribution to the conservation of global genetic resources. Despite this, the four introduced goat individuals lead to an OECD-indicator increasing by 4 %. That's why the number of registered breeds in the way this indicator is used by the OECD is not a very significant parameter for biodiversity. An alternative might be to differentiate between native breeds – with a high national responsibility for conservation – and non-native breeds with, in general, a low responsibility.

An overview of the OECD indicators and our own suggestions of modification and expansion is given in Table 1. The respective proposed indicators are subsequently presented in the chapters 3.1 and 3.2. The required data to implement these indicators are widely available, at least within the EU.

Table 1: Overview of the OECD livestock and crop biodiversity indicators (*in italics*) and our own proposal of modification and expansion (with numbers)

Livestock biodiversity	Crop biodiversity
	1. Number of crop species in agricultural use (new)
	2. Crop species ratio / diversity index (new)
Number of registered livestock breeds	*Number of registered crop varieties*
→ 1. Number of key livestock breeds (native endangered, native not endangered, non-native)	→ 3. Number of key crop varieties (domestic, non-domestic)
Share of key livestock breeds in livestock numbers	*Share of key crop varieties in marketed production*
→ 2. Share of the three major livestock breeds (additional information: native, non-native breeds)	→ 4. Share of the three major crop varieties in seed production area / diversity index
Number of endangered national livestock breeds	*Number of endangered national crop varieties*
→ 3. Native breeds' population size and status of endangerment (see also 1.)	→ in Germany not feasible yet
4. Application of high-selective breeding methods (new)	5. Share of genetically heterogeneous and homogeneous varieties (new)
	6. Share of varieties with and without ‚evolutionary potential' (new)
5. Number of breeder's associations (new)	7. Number of breeders per crop (new)

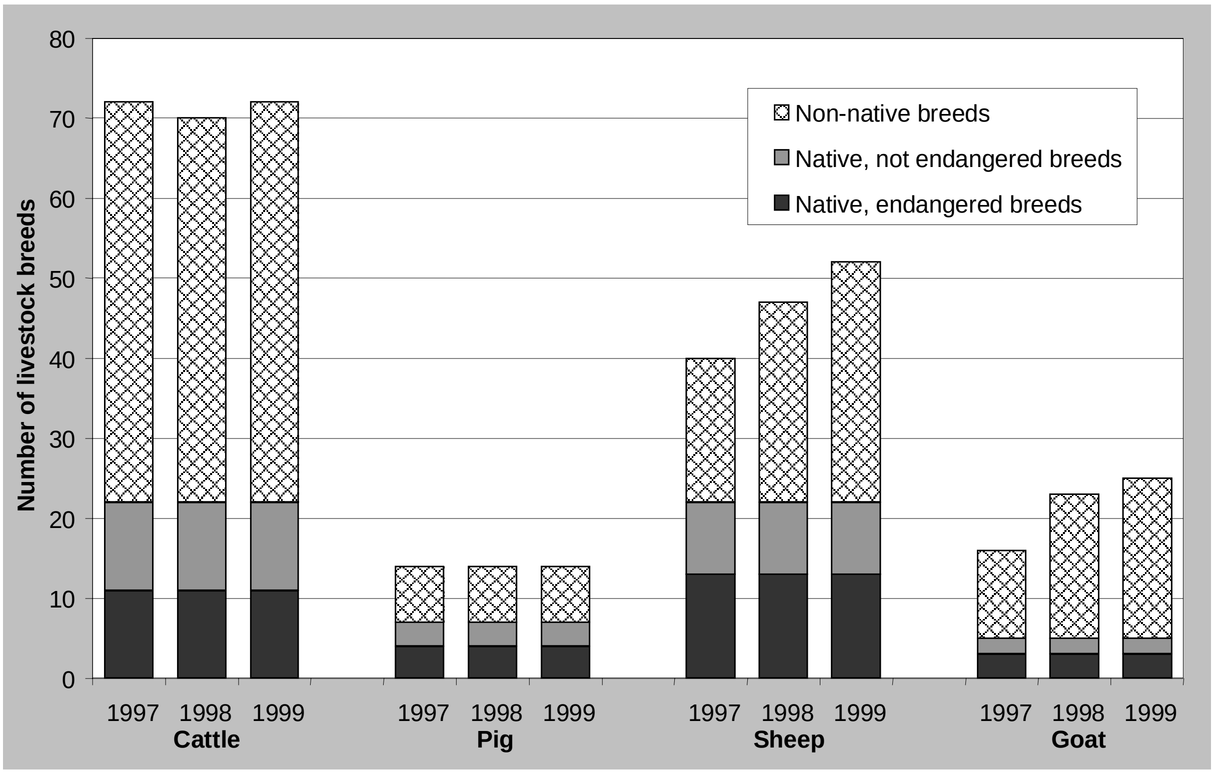
Source: OECD, 2001; own

3.1 Appropriate indicators of livestock biodiversity

3.1.1 Number of key livestock breeds

Figure 2 shows the modified OECD-indicator with the number of native and non-native breeds registered in the German herd-books for the main livestock species cattle, pigs, sheep and goats. The native breeds are classified whether they are endangered according to the red list of endangered domestic animals (GEH, 2001).

Figure 2: Number of key cattle, pig, sheep and goat breeds registered in the German herd-books



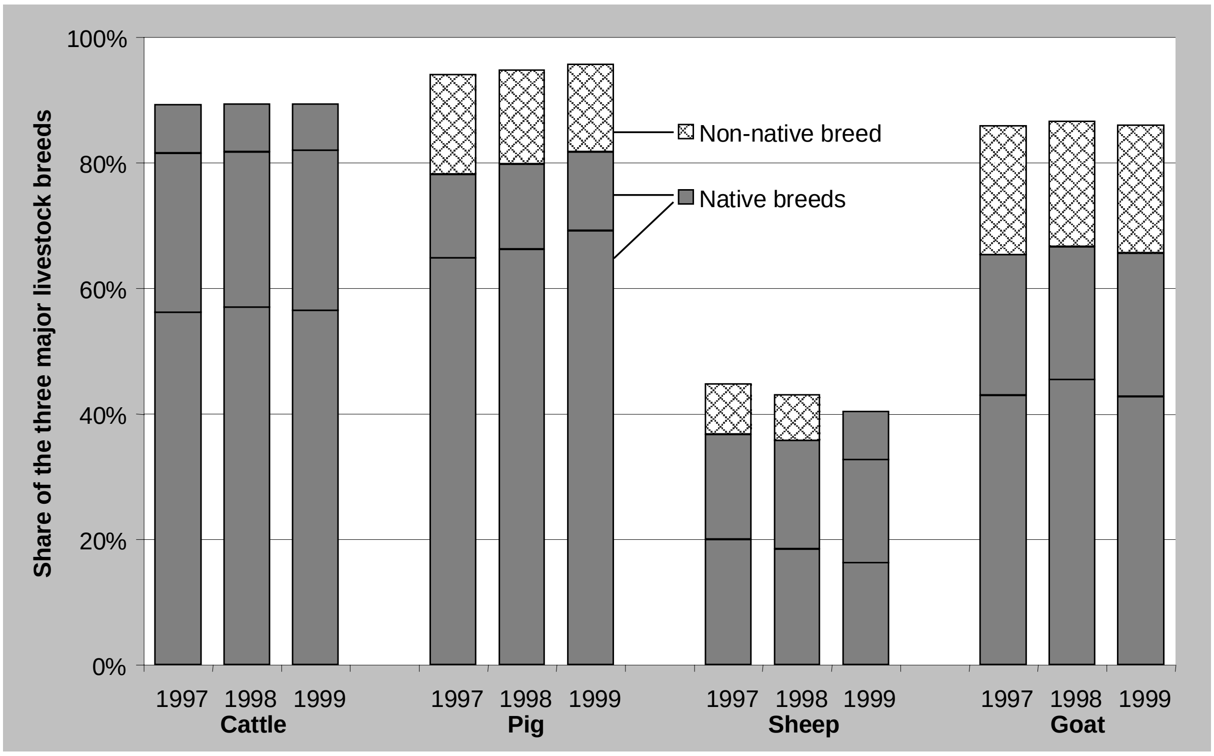
Source: Calculated of the data from IGR, 2001; GEH, 2001

The figure reveals, that the number of native breeds remained constant for the considered period, while several ‚exotic‘ non-native breeds were introduced and newly registered. So genetic diversity does not really seem to have been enhanced, but more distributed around the globe.

3.1.2 Share of the three major livestock breeds

The share of major livestock breeds in total livestock numbers is another indicator proposed by the OECD. We suggest to enhance the information value of this parameter by pointing out the individual three major breeds and whether they are native or not. Figure 3 reveals, that in Germany a positive trend can be detected for the sheep populations.

Figure 3: Share of the three major cattle, pig, sheep and goat breeds in Germany, pointed out, whether they are native or not



Source: Calculated of the data from IGR, 2001

The informative capability of this indicator is limited insofar as the major and the more fragile part of the national genetic diversity is not present within the three common (sometimes even non-native) breeds, but in the whole rest of native breeds. However, the relevant indicator is not the share of these breeds in total livestock, but the size and stability of their populations. Therefore, we propose to complete the OECD set by the following indicators.

3.1.3 Native breed's population size and status of endangerment

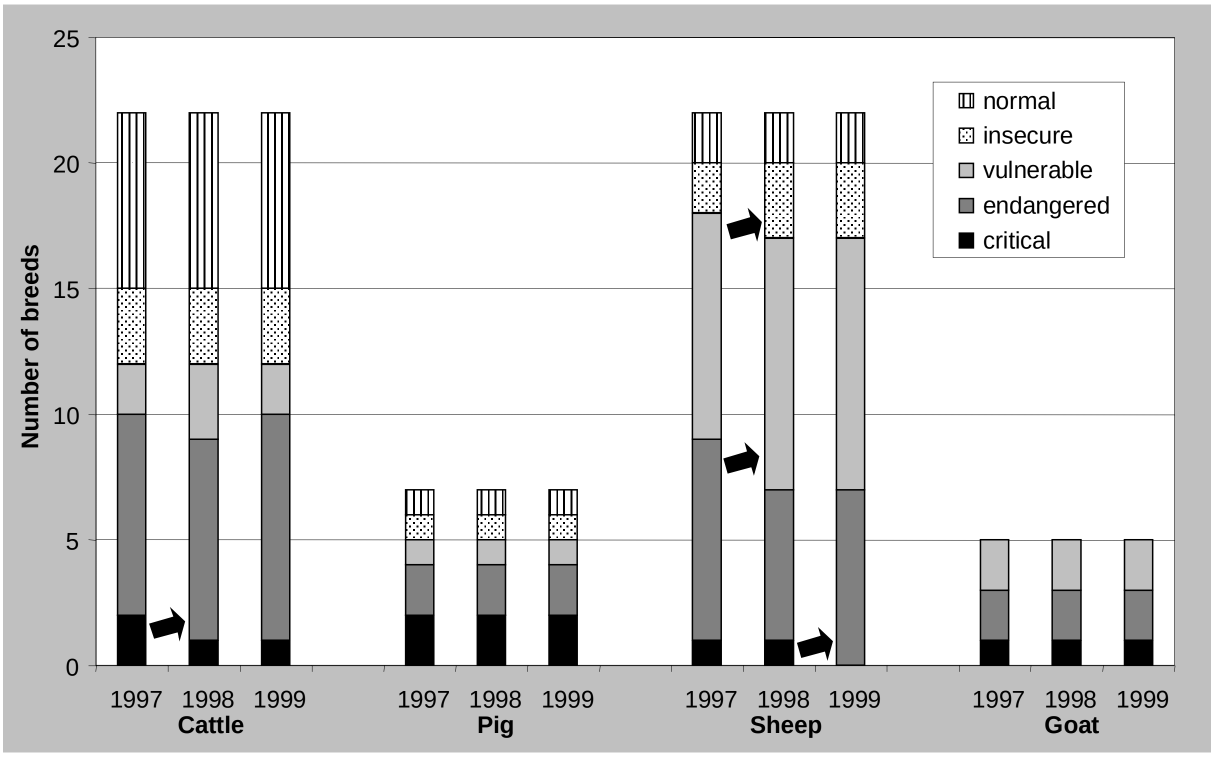
Native breeds, for whom a country carries major responsibility, should be held on a stable population size, preventing extinction and limiting genetic drift. Depending on the actual population size, it is possible to classify the breeds roughly into different status' of endangerment (Table 2). So changes in a population's situation can be traced in a more sensitive way than by using the informations of the red list of endangered livestock breeds (GEH, 2001). Figure 4 shows the development of the population sizes of the German native breeds with respect to their status of endangerment.

Table 2: Classification of livestock populations

Status of endangerment	Population size	
• Critical	< 100	breeding females
• Endangered	100 – 1,000	breeding females
• Vulnerable	1,000 – 5,000	breeding females
• Insecure	5,000 – 10,000	breeding females
• Normal	> 10,000	breeding females

Source: Bodó, 1992

Figure 4: Trends in the status of endangerment of native lifestock breeds according to their population size



Source: Calculated of the data from IGR, 2001; Bodó, 1992

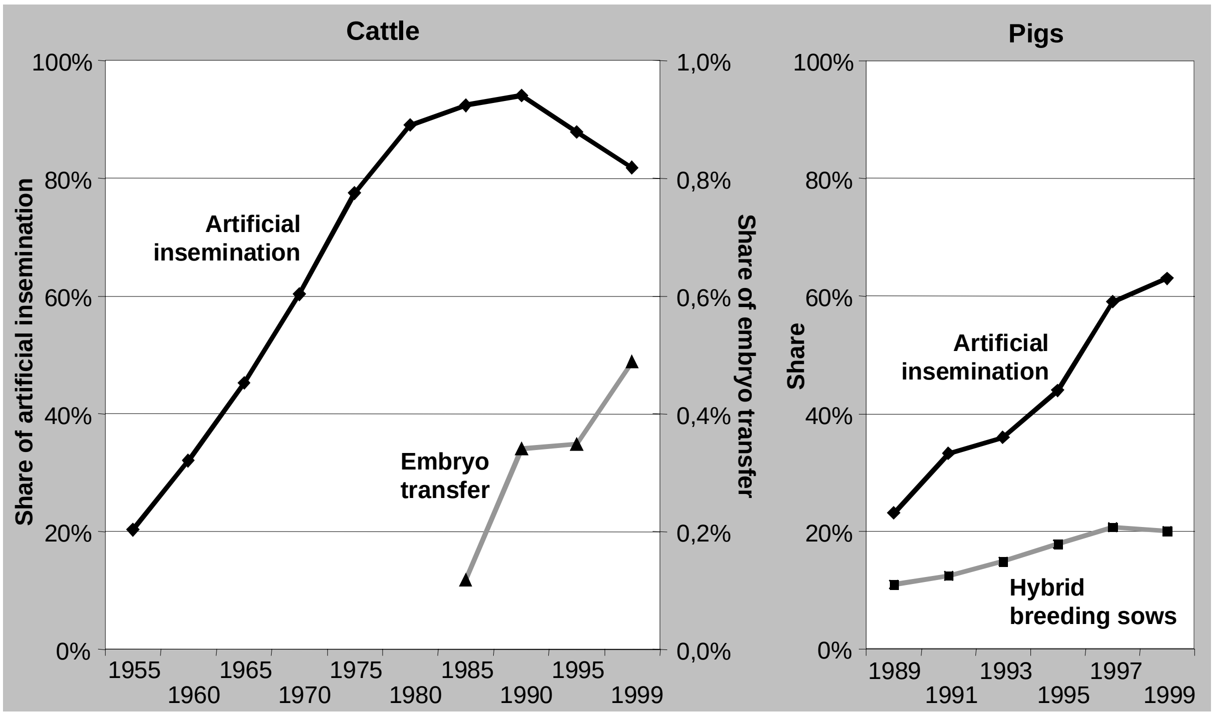
Positive trends in the considered period can be detected for cattle and mainly for the sheep breeds, where meanwhile some small populations have been stabilized.

3.1.4 Application of high-selective breeding methods

The indicators presented above are based on the assumption, that the genetic diversity is equally distributed over all individuals so that the diversity within a breed is more or less directly correlated with the population size. However, it is not considered, that modern breeding methods have uniformed – that is reduced – the genetic equipment of the animals especially within the major, high performance breeds (Sambraus, 1986). Already in 1979, Simon & Schulte-Coerne stated, that the main reasons for the ‚success' of animal breeding are at the same time the fundamental causes for the uniformisation, endangering and loss of domestic animal breeds and populations. Artificial insemination, multiple ovulation and embryo transfer are applied for reproducing the few very top performing individuals only (Kalm, 1991, 1997). Therefore a corresponding number of other animals are excluded from breeding. The dimension of this situation becomes clear when well-known scientists estimate the population-genetically relevant so-called ‚effective populations size' of the German Holstein-Fresians at a range of 50 (!), although the total population has 1.5 million registered herd-book cows.

Hybrid breeding and – in the future – cloning are methods to produce genetically homogenous and high performing livestock material. Impacts on the genetic pool are expected when traditional pure breeding gets replaced by these modern breeding methods. Concerning cattle breeding, artificial insemination and embryo transfer are more or less regularly applied while hybrid breeding is used beside the artificial insemination mainly for pigs (and poultry) (Figure 5).

Figure 5: Application rate of artificial insemination, embryotransfer and hybrid breeding for cattle and pigs (different periods)



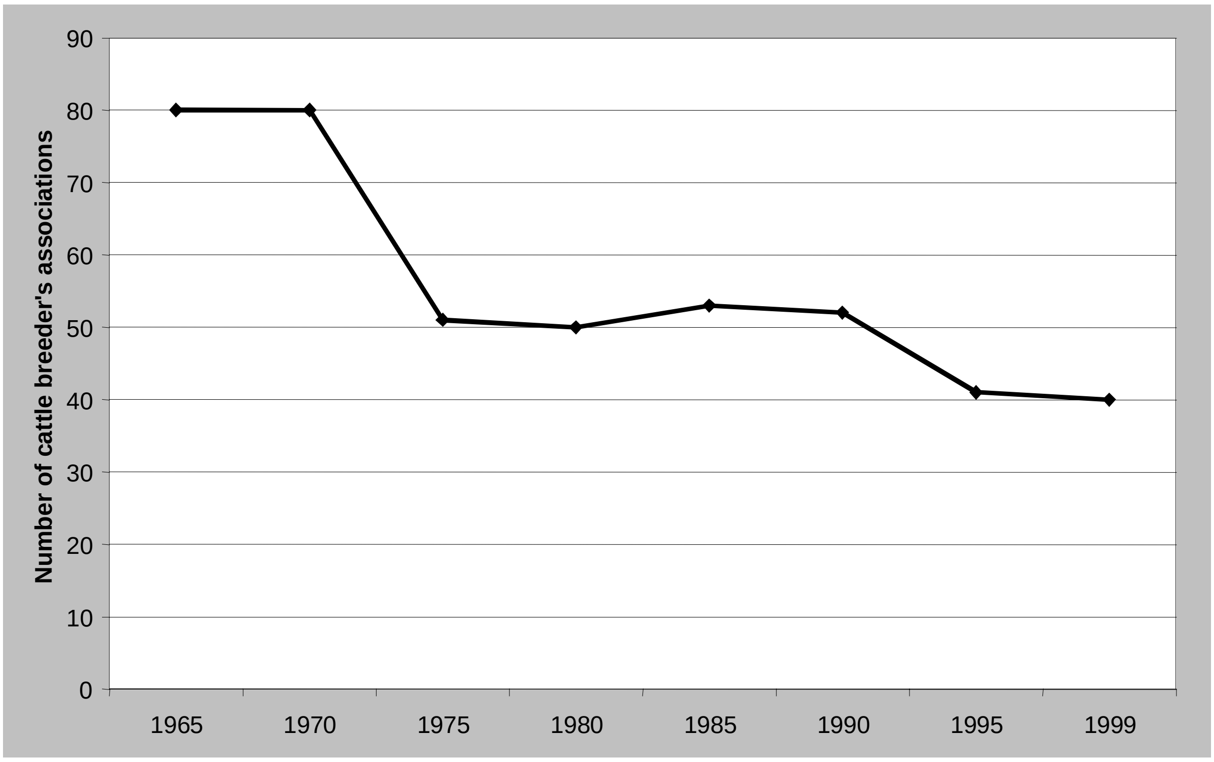
Source: Calculated of the data from ADR, ZDS and StBA, several years each

Up to now, in Germany, sheep and goats are usually reproducing naturally, so that no corresponding negative impact on genetic diversity has to be expected.

3.1.5 Number of breeder's associations

The number of offically accredited breeder's associations is roughly correlated with the number of independent breeding populations. The decrease in the number of breeder's associations as shown in Figure 6 is usually based on mergers. This happens particularly with the objective to merge the previously more or less separate populations in order to increase the selection intensity in the subsequently enlarged population. A higher selection intensity implies an increasing exclusion of individuals from reproduction, coupled with an increasing risk of genetic erosion (Simon & Schulte-Coerne, 1979; Sambraus, 1986).

Figure 6: Number of cattle breeder's associations in Germany



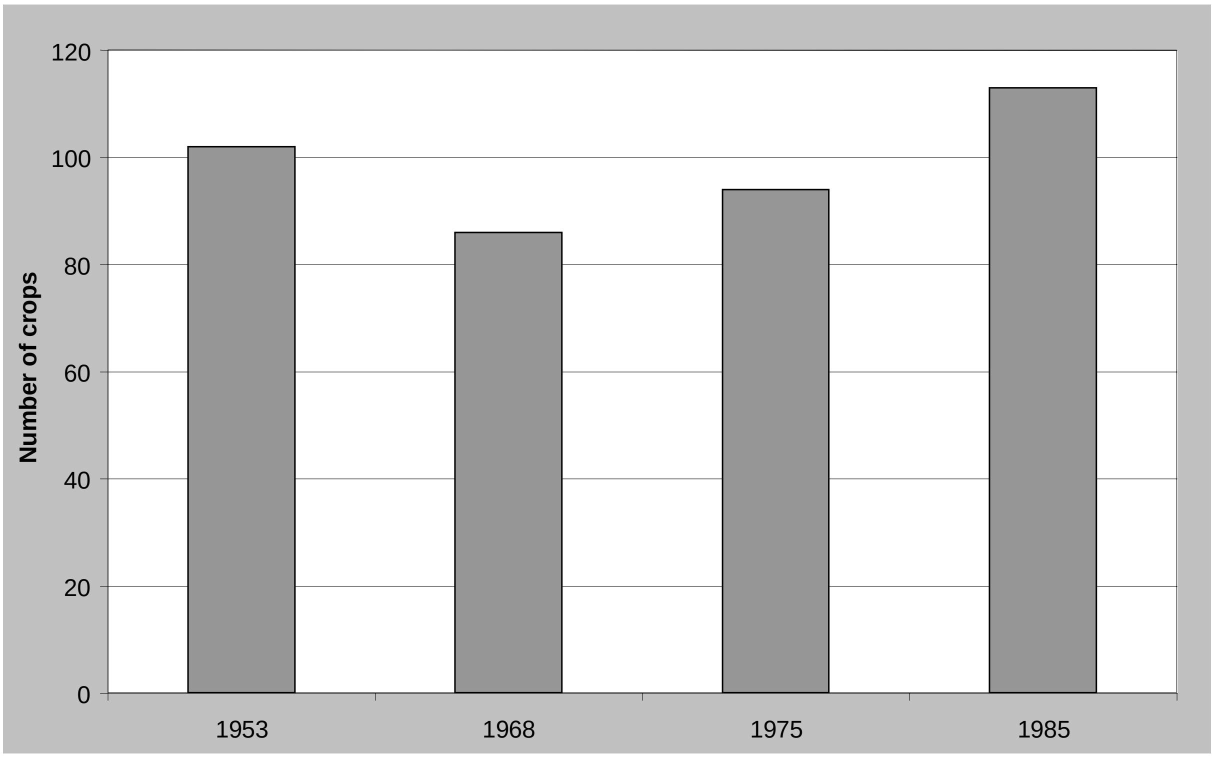
Source: ADR, 2000

3.2 Appropriate indicators of crop biodiversity

3.2.1 Number of crop species in agricultural use

For a qualified and comprehensive set of indicators, crop diversity on the agricultural land has to be captured, which means the number of grown crop species as well as trends in crop ratio have to be assessed. Unfortunately, the number of grown crops cannot be quantified exactly, because only the main crops are covered by the statistics. A rough impression of the development in crop numbers can be derived from the species directory related to the German seed trade act, containing all agricultural and horticultural crops, assessed as economically relevant. Figure 7 shows the changes of the species directory since 1953. Further evaluation should document, whether formerly native crops declined and new ‚exotic' crops increased. The supposed decline of old native crops which were previously uniquely cultivated in Germany is coupled with the irreversible loss of genes. In contrast, many of the new crops can only be grown under glass and are not reproduced in Germany at all, so that there is no relevant German responsibility for conserving their genetic diversity.

Figure 7: Number of crops registered in the different amendments of the species directory related to the German seed trade act (without ornamental plants)

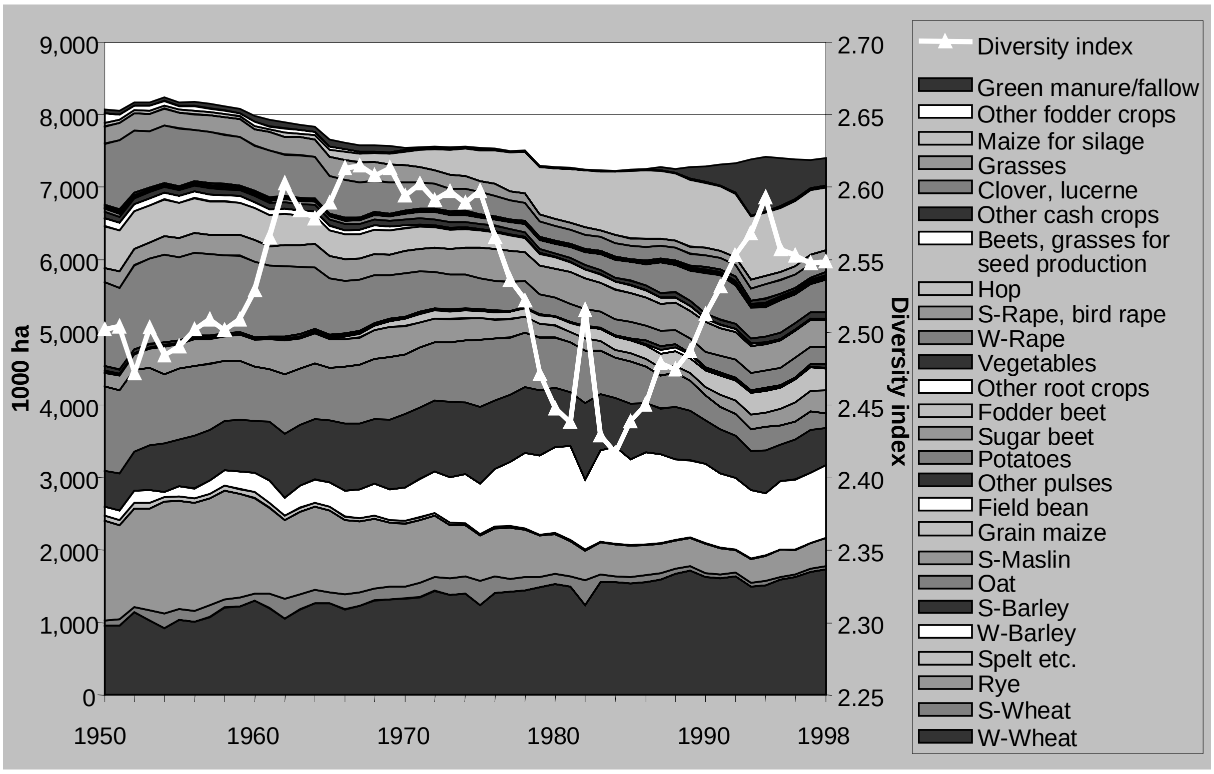


Source: BGBl, 1953, 1968, 1975, 1985

3.2.2 Changes in crop ratio

The number of crops is one aspect of diversity, the share of the individual crops is another. The cultivation areas for those agricultural crops for which data are available, are given in Figure 8. As the data for such a number of crops can hardly be overlooked, the presentation of a diversity index (e.g. Shannon-Weaver Index) seems to be a useful alternative, which is also presented in Figure 8.

Figure 8: Crop area and (Shannon-Weaver) diversity index of cultivation in (West-) Germany

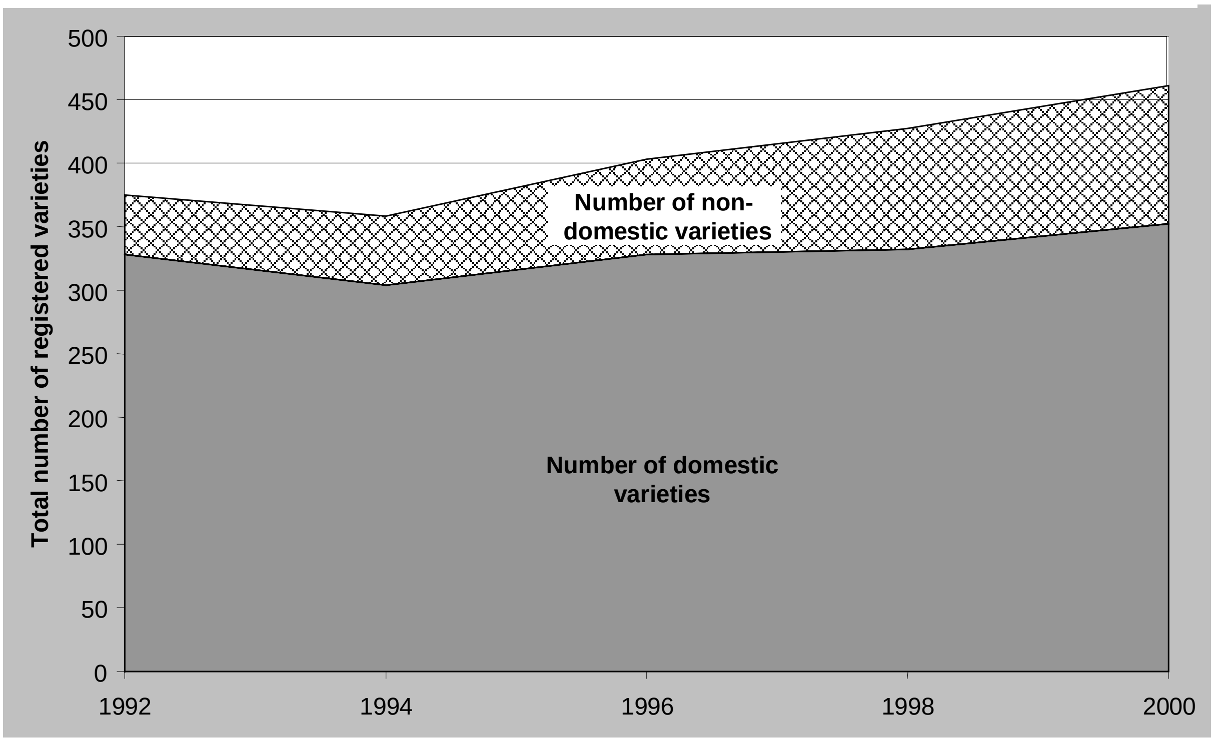


Source: StBA, 2001; own calculation

3.2.3 Number of registered crop varieties

The number of registered crop varieties is an indicator corresponding to the OECD proposal. In times of globalization, there are trends of a worldwide distribution of high performance varieties, which seem to increase the national diversity while at the same time global genetic diversity may perhaps decline. Therefore, we propose the varieties classified as either representing the domestic biodiversity and enhancing global diversity or wether they are traded internationally, so that the country does not seem to be responsible for conserving this genetic material. For pragmatic reasons, the varieties registered by the German Federal Office of Plant Varieties (Bundessortenamt) are distinguished in ‚domestic‘ varieties, whose breeders are located in Germany, and ‚non-domestic‘ varieties whose breeders are situated abroad. An evaluation of maize and cereal crops for the period of 1992 to 2000 shows a slightly rising number of domestic varieties while the number of non-domestic, internationally traded varieties is more than doubling (Figure 9). That means, diversity in Germany seems to be increasing while the German contribution to the global biodiversity remains nearly constant. The investigation should be expanded to other crops including vegetables.

Figure 9: Number of domestic and non-domestic varieties registered at the German Federal Office of Plant Varieties (maize and cereal crops only)



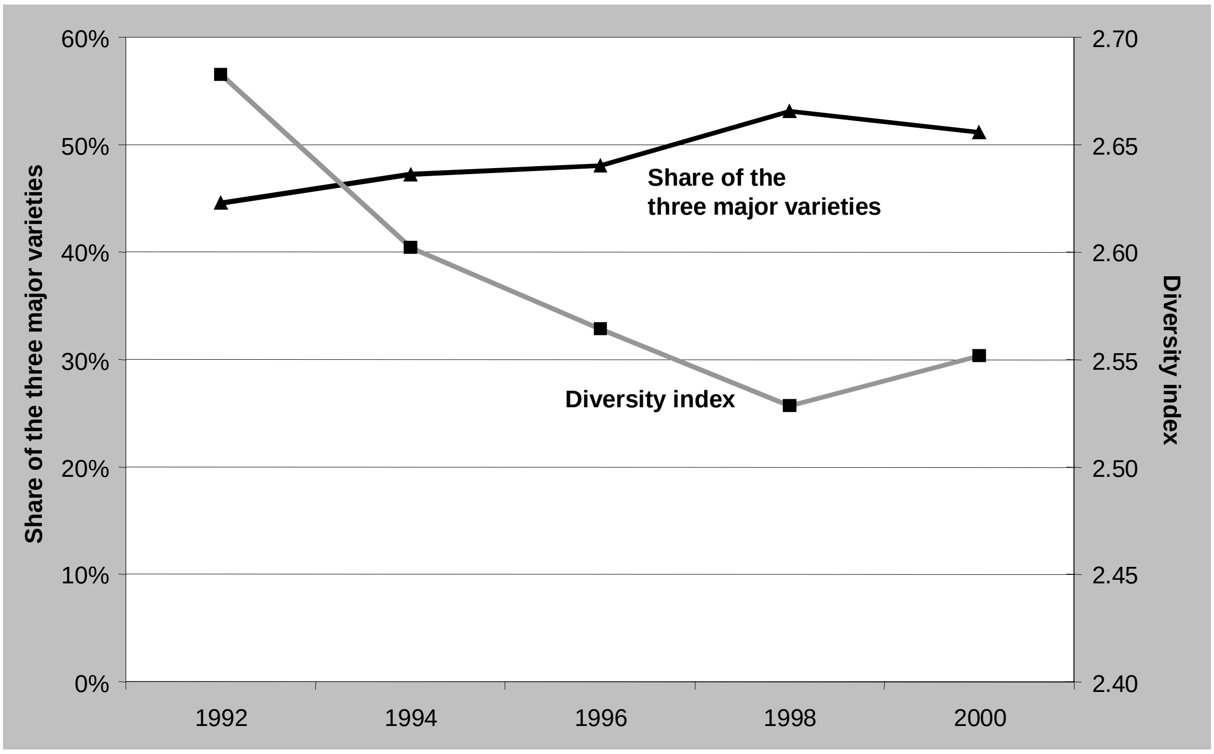
Source: Calculated of the data from BSA, several years a)

3.2.4 Share of major crop varieties / diversity index

The number of registered varieties represents only the potential diversity, which does not correspond with the real diversity on the fields, where often only a few high performance varieties dominate the cultivation. The OECD suggests the share of e.g. the three major (=‘key‘) varieties for each crop in total marketed production to be used as an indicator. As there is no variety-specific information on the production quantity available, the information on seed multiplication areas can serve as a data source, but restricted to those crops mainly multiplied at home in Germany. However, regarding diversity, the cultivation of the varieties beside the three major crops is very important. Because this large number cannot be overlooked anymore, the application of a diversity index, e.g. the Shannon-Weaver-Index, is a useful method. Figure 10 reveals a rather decreasing diversity on the fields, although the number of registered, potentially available varieties is increasing (Figure 9).

Similar to the animal breeds, the trends in numbers and shares of varieties are only partly correlating with the actual genetic diversity, for which a real widespread measurement (e.g. of genetic distances) is not foreseeable for the medium-term. Therefore, different breeding methods and the resulting variety categories can serve as an indicator for the impact of breeding on genetic diversity besides creating a lot of marketable products called ‚variety‘. For example, 30 to 40 wheat subspecies (taxonomic varieties) were cultivated a hundred years ago in Germany, while today, the plenty of (legally formal) varieties are based only on two of these former subspecies. Therefore, a substantial loss of genes may be covered by a high number of varieties, because many varieties are very closely related to each other. That's why we suggest to amend the OECD set of indicators by the following indicators.

Figure 10: Weighted mean share of the three major varieties in total seed production area per crop and weighted average of the (Shannon-Weaver) diversity index of seed production areas per crop in Germany (cereal crops only)

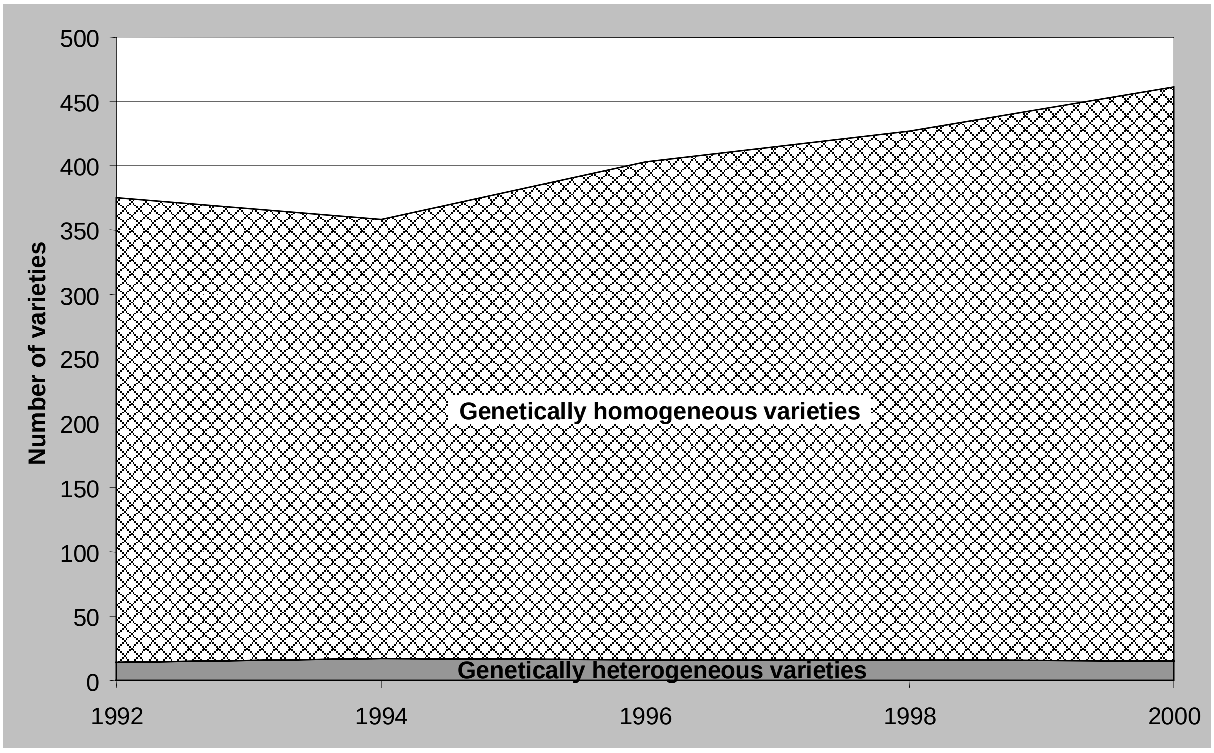


Source: Calculated of the data from BSA, several years b)

3.2.5 Share of genetically heterogeneous and homogeneous varieties

According to different population-biological characteristics and different methods applicated in breeding, there are big differences in how far a variety leads to a higher or lower genetical diversity within a field's population. Therefore, population varieties of allogamic crops like rye and old local varieties are composed of a multitude of genetically different plant individuals. On the other hand, modern line and hybrid breeding results in varieties, which consist of more or less genetically identical individuals. So it is possible to classify the registered varieties by the way they contribute to the genetic diversity in the field (Figure 11). In Germany, all registered varieties of self-pollinating cereal crops must be classified as genetically homogeneous line varieties. Genetically heterogeneous population varieties are existing for the allogamic rye, but also there, hybrids are dominating today. For maize, only one local variety is still registered, all others are hybrids. This indicator would be also very interesting for vegetables, as there are still many local varieties cultivated.

Figure 11: Genetically heterogenous and homogenous registered varieties in Germany (maize and cereal crops)

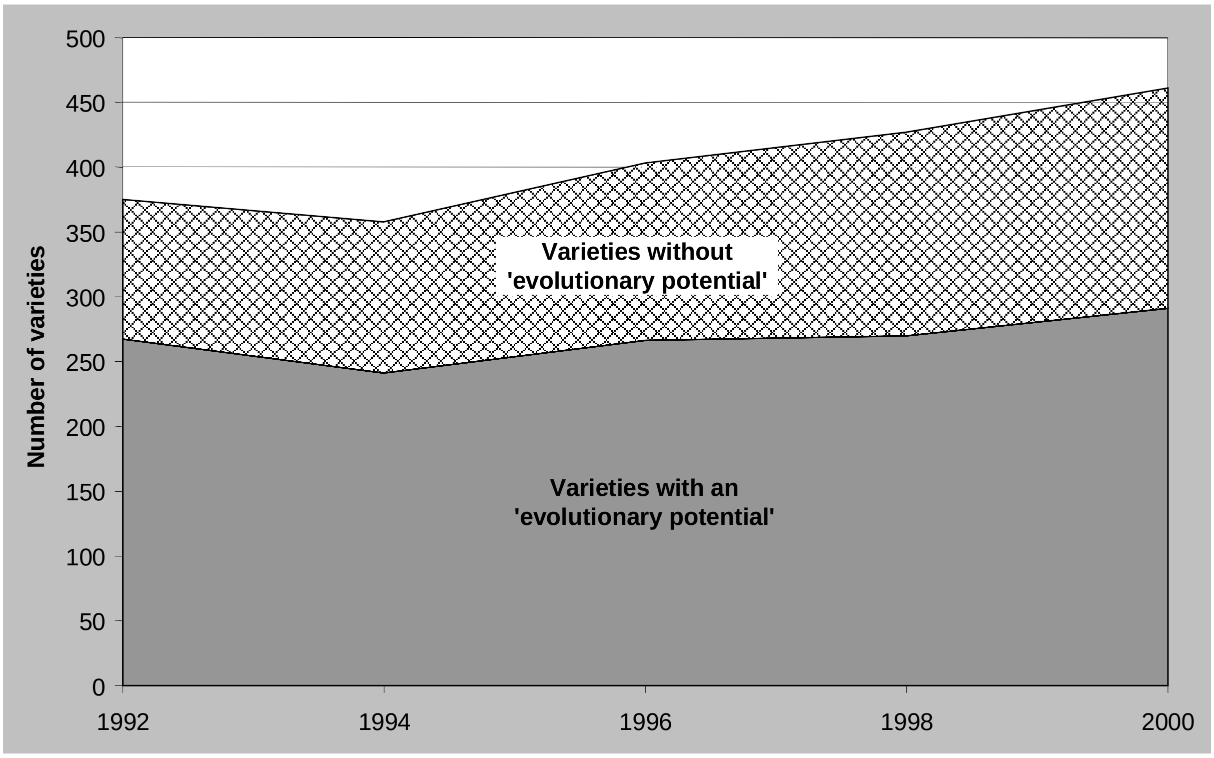


Source: Calculated of the data from BSA, several years a)

3.2.6 Share of varieties with and without ‚evolutionary potential‘

While the indicator above captures a spatial dimension of genetic diversity on the fields, there is also a temporal dimension, when farmers save parts of their own harvest for sowing in the next period (‚farmers privilege‘). When this procedure is beeing pursued for several times, the seeds adapt to site-specific conditions, that means evolutionary processes can evolve and new diversity is created in the medium- and long-term. Unfortunately there are no official statistics on these practices. So in a first step, an indicator could be drawn capturing the suitability of varieties for saving and sowing the own seeds again, that means a kind of ‚evolutionary potential‘ of a variety, not considered if this potential is used or not (Figure 12). In general, all traditional varieties can be assigned to this evolutionary potential. In contrast, for population-biological reasons hybrids are not suited for using the next generation. Genetically modified varieties must not be reproduced, because of technology user agreements, based on the patent law. This indicator may be of very high relevance in less industrialized countries.

Figure 12: Number of registered varieties with and without ‚evolutionary potential‘ (see text) (Germany, maize and cereal crops)



Source: Calculated of the data from BSA, several years a)

3.2.7 Number of breeders per crop

Usually, plant breeding is based on the breeder’s own genetic pool of the relevant crop. That’s why in general the genetic diversity within a crop is higher, the more breeders are working on a crop, each with his own genetic pool. Different varieties of one breeder are often based on the same pool. That’s one reason for the close relationship between many varieties. A high amount of separate breeding programmes counteracts this relationships, though potentially enhancing genetic diversity. Although cooperations between breeding enterprises are increasing, the mean number of breeders per crop may serve as an appropriate and feasable indicator for the width of the actual breeding basis, the genetic pools (Figure 13).

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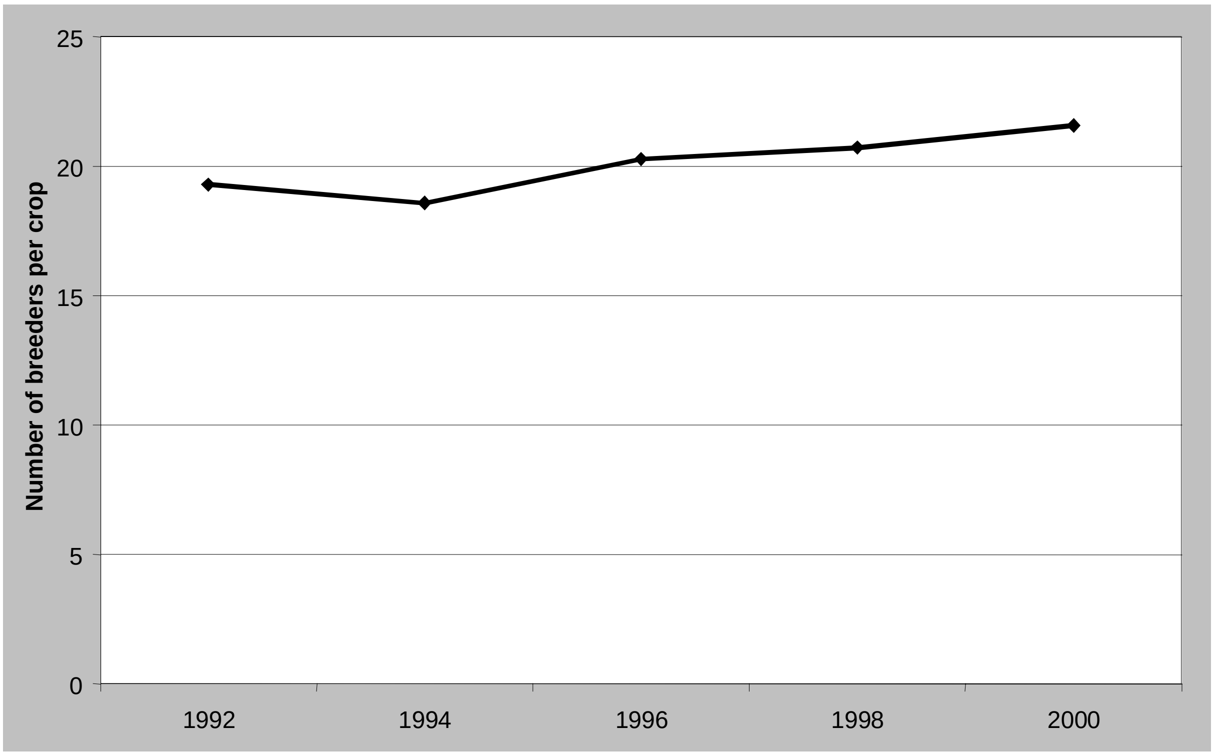
Figure 13: Average number of breeding enterprises per crop (breeding enterprises, which have registered at least one maize or cereal crop variety in Germany)



Source: Calculated of the data from BSA, several years a)

4 Conclusion and Outlook

The livestock and crop biodiversity indicators presented above are regarded to give a more comprehensive insight to the processes influencing agrobiological diversity than the basic OECD indicators. A final judgement on the quantity of genetic erosion (or growth?) of livestock and crops is only possible when widespread measurements of genetic diversity (distances) are implemented. In the former livestock chapter we focussed mainly on cattle, pigs, sheep and goats for which data are widely available. However, we also suggest to include e.g. poultry in the indicators. Unfortunately, the availability of data is weak. In contrast, crop diversity could be easily expanded to oil, root and fodder crops, fruit and particularly vegetables, partly except for the share of key crop varieties for crops mainly reproduced abroad.

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