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1. Introduction, background and context

Many countries have developed national biodiversity strategies and policies dealing with conservation and sustainable use of genetic resources. Usually, the agricultural sector is considered to be a key player in biodiversity conservation. The relationship between agriculture and biodiversity is often called agro-biodiversity. National policies on agro-biodiversity or biodiversity in general require indicators to measure the performance of national policies and help monitor progress in fulfilling international obligations.

The official Dutch government policy relevant to genetic resources is summarized in the document *Sources of Existence: Conservation and the sustainable use of genetic diversity (SoE).* It emphasizes the importance of genetic resources for sustainable development in various policy plans and documents relating to various fields such as biodiversity, nature management, the environment, agriculture and biotechnology. This policy document recognizes the need to develop indicators of agricultural genetic diversity in order to monitor the implementation and impact of conservation measures, whether national, regional or global.

The Netherlands is actively involved in the development and implementation of international commitments. The Netherlands signed the Convention on Biological Diversity (CBD) in 1992. With respect to plant genetic resources, the Netherlands adopted the Leipzig Declaration and the FAO Global Plan of Action of Plant Genetic Resources for Food and Agriculture in 1996 and also signed the International Treaty for Plant Genetic Resources in 2002. With respect to farm animal genetic resources the Netherlands is actively involved in the State of the World's Animal Genetic Resources process and the Global Strategy for Farm Animal Genetic Resources, co-ordinated by FAO. In this context, the Dutch government developed a national report on farm animal genetic resources in 2002. Furthermore, the Netherlands is a member of the WTO and thus a party to the TRIPS agreement and a party to the 1991 Act of the UPOV Convention.

Other international conventions include conventions on wild flora and fauna, endangered species and wetlands, all referring to nature and environment protection. Agro-biodiversity has of course a relationship with other biodiversity domains, which is a rather complex relationship. Agricultural production is often considered as a major contributor to the loss of biodiversity. However, agricultural ecosystems can also serve to maintain biodiversity.

According to OECD, 1996 (p. 20), the importance of biodiversity for agriculture involves:

- Facilitating the functioning of ecosystems, such as nutrient cycling, protection and enrichment of soils, pollination, regulation of temperature and local climates, and watershed filtration;
- Providing the source of most of the world's food and fibre products, including the basis for crop and livestock genetic resources, their improvement and the development of new resources, and
- Offering a range of scientific, health/medicinal, cultural, aesthetic, recreational and other intangible (and non-monetary values) and services from biodiversity richness and abundance.

The CBD (1992) considers biodiversity in terms of three levels:

- *Genetic* diversity (within species)
  The diversity of genes within domesticated plants and livestock species and wild relatives;
- *Species* diversity (between species)
  The number and population of wild species (flora and fauna) affected by agriculture, including soil biota and the effects of non-native species on agriculture and biodiversity;
- *Ecosystem* diversity (of ecosystems)
  The ecosystems formed by populations of species relevant to agriculture or species communities dependent on agricultural habitats.

These three levels are not independent but interact. A loss or change of species or genetic diversity within species can influence ecosystem diversity and vice versa.

Genetic diversity in plants and animals forms the basis for (future) agriculture. On a global level, both for plants and animals, genetic erosion has taken place in terms of loss of breeds and varieties and loss of diversity within breeds and varieties. Genetic improvement programs have helped to increase productivity and efficiency of agriculture and livestock. Focus on productivity of species and breeds and on uniformity in production resulted in a loss of breeds and varieties with the remaining breeds being less diverse but producing ever more. On the other hand, there is concern about the decrease in genetic diversity in genetic resources for food and agriculture, and an increasing awareness and social commitment to find solutions for this problem and to develop strategies and policies in order to influence the trends.

Sector/thematic area → **↓ Level of biodiversity**	Forests & natural areas	Water	Agriculture
Ecosystem		....	
Species		....	
Genetic		....	includes genetic diversity of crops & livestock

Figure 1. Levels of biodiversity by sector.

Status and changes in (agro) biodiversity on three levels as mentioned above can be analyzed on a global, regional or national level. In order to monitor changes in diversity on these three levels, indicators are needed. The sets of indicators to monitor biodiversity are potentially very large. Many studies have been undertaken to develop useful indicators, partly dealing with the relationship between agriculture and biodiversity. Emphasis has been laid on different levels of agro biodiversity: diversity of (agro) ecosystems, between-species diversity and within-species diversity.

The focus of this study is on indicators for genetic resources, relevant for food and agriculture, for future food security and other functions of genetic resources or agro-biodiversity. This is one small area in the range of levels and sectors (see Figure 1). It is recognized that there are many interrelationships between biodiversity and agriculture, between wild species and agricultural species and between ecosystem and genetic diversity. However, from the perspective of conservation and sustainable use of genetic resources for food and agriculture, there is a need for specific, quality (sets of) indicators, which help policy makers to monitor policies and for 'early warning' purposes. Genetic resources for food and agriculture have received some attention in international fora such as the CBD, the OECD and the FAO, but not as much as indicators for other sectors and levels of biodiversity.

The objectives of this study were

- To analyse the (potential and realised) value of available indicators for monitoring and evaluation of agro-biodiversity and of plant and animal genetic resources in particular
- To develop and recommend options for the application of various indicators for monitoring of the status of genetic resources.
- To contribute to the international debate on indicator development.

This study was undertaken by the Centre for Genetic Resources, the Netherlands in collaboration with both the Animal Sciences Group and the Agricultural Economics Research Institute of Wageningen University and Research Centre. The study is funded by the International Co-operation Research Programme of the Ministry of Agriculture, Food Quality and Nature Management of the Netherlands.
Chapter 2 starts with a description of the theoretical framework to assess (sets) of indicators. In chapter 3 literature on agro-biodiversity indicators is reviewed and different options for sets of indicators are listed. In chapter 4 the proposed indicators will be tested in a number of case studies (crops, animals, developed country, developing country). The report will be finished with conclusions and recommendations for policy makers.

2. Basic concepts

Pressure state response framework

Indicators of genetic diversity are usually associated with measuring the current extent of diversity present in crop varieties and animal breeds. These are examples of indicators of the current situation (snap shots). From a policy or management perspective, it is also necessary to think about what factors are causing the current state of affairs and what, if any, appropriate actions need to be undertaken. For this purpose, the *pressure-state-response* framework has been developed for examining environmental issues and the development of appropriate indicators (OECD, 2003c).

The *pressure-state-response* framework highlights the need to formulate indicators at three levels. The state of genetic diversity is nested between pressures and responses (see Table 1). The framework thus concentrates on developing an understanding of cause-effect relationships by which underlying and immediate pressures lead to changes/trends in the state of genetic diversity. In addition, there is explicit attention for responses by various stakeholders to address this situation by affecting these pressures or their effect upon genetic diversity.

As discussed in Chapter 1, our main concern in this study is essentially genetic erosion in terms of loss of breeds or varieties, and also a loss of diversity within breeds or varieties. These two levels of genetic erosion are represented under the column, 'State' in Table 1.

Table 1. A pressure-state-response framework for genetic erosion in agricultural crops and livestock.

Pressures	State	Response
Underlying (indirect) • Economic growth and integration of markets • Intellectual property right regimes • Extensification and Intensification • Homogenisation of production systems • Increased efficiency of technology diffusion (i.e. biotechnology, reproduction technology) Immediate (direct) • Breeding goals • Availability of (fully characterized) genetic resources	• Diversity between livestock breeds/crop varieties • Diversity within livestock breeds/crop varieties	Conservation • In situ • Ex situ Stimulating use • (Pre-)breeding • Characterization • Subsidies

Concepts of diversity

Diversity can be looked at from different angles and this can lead to different types of measures. We follow the approach that has been pursued in economic and policy-oriented research on genetic diversity in major staple crops of Meng *et al.* (1998) and Smale *et al.* (2003), who draw on the classification of ecological indices of spatial diversity of Magurran (1988), which leads to three concepts of diversity:

- **Richness** refers to the number of species at an inter-specific level (typically the focus of ecological studies), and the number of breeds or varieties at an intra-specific level.
- **Abundance** refers to number, or distribution, of individuals of a given species (or breed/variety) in a population of interest. The concept of abundance thus concentrates often on the dominance of the most commonly-occurring species (or breed/variety).
- **Evenness** refers to the equality of relative or proportional abundance of all species (or breeds/varieties) in a population of interest. Evenness measures the relative shares.

It is readily apparent that indicators of richness are of fundamental relevance. The amount of diversity is viewed as being quite different depending on perspectives of abundance and evenness. For example, if there are five breeds of cattle used in dairy production in a country, it makes quite a difference whether the most common breed accounts for 30% or for 90%. But, conversely, if the most common breed accounts for 90%, it makes quite a difference whether the remaining 10% is comprised of one, two, three, or more breeds. Thus a set of indicators is needed that covers both richness as well as some aspects of abundance and/or evenness.

In such an approach, a *concept* of diversity is distinguished from the *index* employed. An index is a specific mathematical formula. For example, for richness, the index typically consists simply of the total number of species, breeds, or varieties present. But for concepts of abundance and evenness, a number of alternative indices may be available. A commonly-used index of evenness is the Shannon index (Magurran, 1991), which is discussed in chapter 3.

Some limitations of this framework need to be acknowledged. As with any cause-effect framework, there are many ways of categorising pressures, for example between immediate (direct) and underlying (indirect), and thus possibilities for extending the steps in the chain. There are no golden rules as to the appropriate level of detail or as to whether an element is better viewed as a pressure or an indicator of the state. A fair amount of arbitrariness applies.[1] Secondly, although presented generally as a chain, a circular systems concept is more appropriate, with responses in turn affecting pressures. Furthermore, such a framework really needs to be seen as a simplification of some processes within a broader, complex system with multiple feedback and two-way relationships.

In general, attention has focused on indicators of the *state* of genetic diversity and to some extent on *responses*, as will be seen in section 3. These may be of highest priority from both a policy and scientific perspective. Indicators of pressure present a number of conceptual difficulties but some suggestions have been made.

Apparent and latent diversity

Apparent diversity refers to variation in physical characteristics either within or among crop varieties or animal breeds that is observable by farmers or scientists (Meng *et al.*, 1998). Indeed varieties and breeds are a means of classifying sub-populations of species according to apparent differences. Latent diversity refers to diversity at the molecular level, which may be of most relevance from a scientific point of view.

1 This is commonly recognized in the application of such frameworks in environmental sciences (Groot, 1997).

3. Review of agro-biodiversity indicators

There is a large body of literature on biodiversity indicators. The bulk of this literature considers indicators of biodiversity at ecosystem and species level, with an emphasis on natural/protected areas and wild/undomesticated species. The discussion in this chapter proceeds by first highlighting briefly the indicators selected to monitor the loss of genetic diversity of wild/undomesticated species. The discussion then turns to indicators of diversity within species of domesticated animals and cultivated plants important for agriculture. Existing sets of suggested indicators of genetic diversity of livestock breeds and crop varieties are reviewed. Based on perceived shortcomings with respect to analytical soundness, an extended list is then proposed, of which a smaller subset could serve as a core, restricted list. The chapter concludes with a review of the potential indicators of latent diversity, which measure diversity at the DNA level.

Wild species

Of the large number of possible indicators, two were selected by the Parties of the CBD at COP7 in Kuala Lumpur (2004) for further use:

- The remaining area of nature
- The number of individuals of species, which are characteristic for specific ecosystems

These indicators meet most of the criteria suggested for evaluating indicators (discussed in the next chapter). They are easy to interpret and can be applied at different levels, regional to global. They also cover the different levels of organization: *ecosystems* by the area of nature and because *their key* species are used, species because species are investigated and genetic diversity because the number of individuals is directly related to genetic diversity. An important argument was that the number of species per se is not so relevant. Pest species and/or non-native species can increase the number of species but are rather a threat to biodiversity than beneficial for biodiversity. By limiting the attention to key-species, that is species characteristic to specific ecosystems, this problem is avoided. These indicators are useful for general use, but for specific purposes and more detailed questions, such as which factors influence biodiversity, they need more elaboration. Particularly the lower aggregation level, within species diversity, is missing in these two indicators. A set or palette of (additional) indicators should make it possible to analyze status and trends on different levels for specific purposes.

Agricultural species and levels of organization

Although wild species and domesticated species are to a large extent similar, the two indicators mentioned above are not suitable for agricultural species. The unit generally considered in agricultural species are livestock breeds and crop varieties and not the species itself. This is an important difference, since as a consequence gene flow between breeds/varieties is theoretically without limit, while gene flow between species is normally absent. Nevertheless problems to be solved in order to select relevant indicators run to a large extent parallel between wild species and agricultural species, the exception being the relative attention given to the three levels of organisation (ecosystem, species, genetic diversity).

Relationships between different agricultural species, thus speaking at the level of ecosystems, are less relevant to the biodiversity of agricultural species, since species are generally maintained separately or grown in mono-cultures. However, agriculture itself is very important for the biodiversity of wild species at the ecosystem level. In this respect the kind and number of species on farms is not so important, whereas the intensity of production is of overall importance. For example, biodiversity in wheat fields can be extremely low in fields where lots of fertiliser, herbicides and insecticides are used. Whereas in 'old-fashioned' plots, where these production increasing tools are not used, biodiversity can be high, with lots of different weeds and accompanying insect life. Thus growing wheat, or any other species, is not so much important for biodiversity but the way it is grown. Nevertheless, a link with species, breeds or varieties is there in that some species (e.g. spelt) or breeds or varieties are less suitable for a high production environment.

The species level is also less important for biodiversity of domesticated species. An increase in the number of domesticated species is generally the consequence of the introduction of exotic species, for example alpaca's and ostriches in the Netherlands. Although the number of species is not important for agro-biodiversity there is a link with biodiversity of wild species. Growing, or keeping, a single species over a large part of a region will make the landscape monotonous, whereas different agricultural species in a small area may create a mosaic of landscapes with an increased biodiversity. Thus both species and ecosystem level are less relevant for the diversity of domesticated species themselves. However, there is an important, but indirect, link with diversity of wild species at these higher levels of organisation.

With respect to the genetic diversity level, biodiversity is at first sight related to the number of livestock breeds and crop varieties. This can be quite literally since breeds generally differ in morphological aspects such as for example coat colour or fruit size. Biodiversity is quite noticeable if each region has, for example, its own type of cow, wheat variety or landraces. It is therefore not surprising that the number of breeds/varieties is often mentioned as the indicator for agro-biodiversity. However, from the perspective of conservation and (future) sustainable use of genetic resources, genetic diversity within for example livestock breeds is as much important as between breed diversity.

Existing indicators

A number of indicators for agricultural species have been proposed in various fora. The discussion here begins with indicators that have been accepted in CBD discussions and by the OECD for further development. Perceived deficiencies in these sets of indicators lead to a review of a more comprehensive set presented at an OECD Expert Meeting by Wetterich (2003). While this set is seen as better, additional indicators are proposed in the following sub-section. A list of potential indicators for crop genetic diversity has also been discussed by a FAO-IPGRI Expert Meeting (FAO, 2002) and some of those are included in the additional indicators proposed below.[2]

CBD indicator

The Seventh Conference of the Parties (COP7) to the CBD requested the Subsidiary Body on Scientific, Technical and Technological Advice (SBSTTA) to further develop indicators on biodiversity, including indicators of the trends in genetic diversity of domesticated animals and cultivated plants (CBD, 2004). The following are the specific indicators for trends in agricultural genetic diversity being considered by the SBSTTA for further development: [3]

- Total number of livestock breeds
- Total number and share of main crop varieties

The share of main crop varieties is added to describe 'the evenness of biodiversity in use and the vulnerability'. The idea is that the lower the share of the dominant varieties the more diversity within the crop species. It is somewhat surprising that a similar measure is not suggested for livestock breeds, but there is a mention that population size of breeds should be taken into account to assess diversity within breeds.

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2 The FAO-IPGRI Expert Meeting made a distinction between indicators of three inter-related concepts: genetic diversity, genetic erosion and genetic vulnerability, noting though that it can be difficult to categorize indicators into only one of these areas. In the present report, attention is focussed primarily on indicators that can contribute to monitoring genetic erosion which is the same as a loss of genetic diversity. The FAO-IPGRI Expert Meeting also devoted more attention than that of the OECD to indicators that would be relevant for the processes underway in many developing countries in "traditional" farming systems.

3 These are described in CBD (2003c). At COP7, a list of provisional biodiversity indicators for assessing progress towards the 2010 Biodiversity Target were identified for immediate testing. However the proposed indicators for agricultural genetic diversity were classified as "possible indicators for development by SBSTTA or Working Groups" (CBD, 2004).

OECD indicator

A list of indicators developed by the OECD (2001) is somewhat more extensive:

- Total number of crop varieties/ livestock breeds registered and/or certified for marketing
- Share of key crop varieties in marketed production (by species/crop)
- Share of key livestock breeds in total livestock population (by species)
- The number and share of national crop varieties/ livestock breeds that are endangered

The key-breeds/varieties referred to in the second indicator are the dominant breed/varieties in terms of production (e.g. Holstein-Friesians and Jerseys in dairy cattle). The idea is that biodiversity is larger if dominant breeds have a smaller share. The last indicator is added to monitor genetic erosion in the much wider gene pool than just those that are marketed for production. A main disadvantage of the first indicator is that an increase in numbers does not mean that the biodiversity has increased. Many new varieties are slight variations of already popular high production varieties/breeds with to a large extent the same genome. A similar problem exists with the second indicator. If a new variety is formed almost similar to the existing dominant variety the share of the dominant variety may go down. Yet the total share of both varieties may increase at the expense of more diverse varieties. The conclusion in the OECD report that the first two indicators 'reveal that diversity has increased since the mid –1980-s' is thus doubtful, to say the least. The problem is quite similar to the non-native and or pest species for wild species. The number of species can increase while at the same time forming a threat to biodiversity. This problem was solved by using the number of individuals of key-species, that is species specific to ecosystems, as an indicator.

Wetterich's indicators

At the OECD Expert Meeting on Agri-biodiversity Indicators in 2001, Wetterich (2003) proposed a more comprehensive set of indicators for livestock biodiversity which helps to address some of the inadequacies of the OECD list:

- Number of key livestock breeds
  - native endangered
  - native not-endangered
  - non-native
- Share of the three major livestock breeds
  - native/non-native
- Population size native breeds
  - status of endangerment
- Application of high-selective breeding methods (such as embryo transfer)
- Number of breeders associations per breed

For crop biodiversity very similar indicators are advised:

- Number of crop species in agricultural use
- Crop species ratio / diversity index (Shannon Weaver index)
- Number of registered crop varieties
  - domestic
  - non-domestic
- Share of three key crop varieties in marketed production
  - seed production area/ diversity index (Shannon Weaver index)
- Number of endangered national crop varieties
- Application of modern breeding methods
  - share of genetically homogeneous and heterogeneous varieties
  - share of varieties with and without evolutionary potential
- Number of breeders per crop

The diversity index (Shannon-Weaver index) translates the number of species/varieties and the evenness of their shares into a single number, decreasing with less species and decreasing if one or a few species take a large share. Varieties without evolutionary potential refer to, for example hybrids that cannot evolve further once used on farms.

The indicators on application of high selective breeding and on the use of (non-) heterogeneous varieties, varieties without evolutionary potential are added to better cover the within variety diversity. In fact these indicators classify most modern breeds/varieties as non-diverse and of less value to biodiversity.

An alternative indicator with respect to crops would be the percentage of crop seeds originating from the farms themselves. Modern homogeneous varieties, without evolutionary potential, are generally delivered by seed companies. In contrast farmers may (partly) use there own stock of seeds, harvested from last years growth. They then use there own, probably more diverse, gene pool, distinct from other gene pools at other farms. The number of breed organisations is also there to better cover within breed diversity. If there are more organisations with more or less separate gene pools and somewhat different selection goals diversity will be higher than if there is one breeding organisation with a generally a smaller gene pool and a 'straight forward' selection goal. This may also be relevant for crops where hybrid breeding strategies dominate as a similar, though probably less pronounced, segregation of genetic pools takes place.

Additional indicators

The extended set of indicators proposed by Wetterich (2003) covers between-and-within-genetic-diversity much better than the OECD indicators. Some gaps still exist. Looking at the pressure-state-response framework, may lead to possible additional indicators.

The underlying pressures behind genetic erosion are many and complex. As portrayed in Table 1, they are generally related to the long-term trends towards capital-intensive, market-oriented agriculture. Without going into too much detail, one relatively simple indicator may capture part of the underlying forces:

- Average size of farms
    - Average area per farm in ha
    - Number of animals (for livestock) or kg production (for crops or livestock) per farm
    - Animals or kg production per hectare

This indicator set captures both the intensification (i.e. higher production per animal or hectare crop) and the trend towards larger farms, which to some extent runs parallel with the trend towards a more efficient, high technology, labour extensive production.

Turning to the immediate forces the following indicator can be used:

- Number of active breeding organisations

Immediate forces concern the trends in the number of breeding goals and strategies being pursued. An important aspect of the range of breeds or varieties that are available concerns the replacement of one breed or variety by another at farm level. One crop variety is often replaced in part by an almost identical variety. By looking at the breeding goals one could identify whether the change in breeds/varieties is a superficial or more fundamental change. Also different breeding programs that pursue the same breeding goals may result in different breeds/varieties that are almost identical. For this reason, some indicator based on the range of breeding goals pursued, may be useful. But this can be quite difficult to monitor, particularly among private sector breeders where such information tends to be guarded quite secretly as it is of strategic importance. Thus the number of active breeding organisations (companies, institutes, etc.) may serve as a proxy measure. A related alternative would be the number of individual breeders currently active.

One problem with the policy usefulness of indicators of genetic diversity is that there are currently very few means by which governments exert influence on the diversity of genetic resources at the level of livestock breeds and crop varieties. However, response indicators should depend on both policies and also the actions of other stakeholders, such as NGO's active in conservation and stimulating use. These two areas were identified in Table 1 and possible indicators are listed below.

The following indicators for conservation efforts (responses) were derived from recommendations of the OECD Expert Meeting (OECD, 2003):

In situ

- Number of breeds/varieties conserved
- Population size by breed/varieties

Ex situ

- Number of breeds/varieties conserved
- Number of accessions/doses by breed/variety

Indicators reviewed up to now are specific for domesticated species. As mentioned in OECD (2000) and several other reports there is an important link between agriculture and biodiversity of wild species. An example is that in the Netherlands one of the strongest decreases observed in wild plants have occurred in weeds of arable land (Mennema *et al*. 1980). This loss is mainly attributed to intensification of production with an increasing use of herbicides. Parallel to the intensification process breeds and varieties used in agriculture have changed. Old breeds and varieties that were adapted to low production circumstances have been replaced by high yielding breeds/varieties.

This suggests the following indicators parallel to the two indicators proposed by the CBD (2004) for wild species (see above[4]):

- Number of breeding males of breeds or varieties grown, characteristic for landscapes/production environments important for biodiversity and characteristic for a region or country.
- Area of low production/high biodiversity

Instead of species characteristic for ecosystems for wild species one could focus for agricultural species on species and breeds/varieties characteristic for specific landscapes and low production environments. One should choose those landscapes/production environments that are known to be important for biodiversity, and characteristic for a region or country. Examples are unfertilised Alpine meadows in the alpine countries or 'bloemrijke hooilanden' (meadows rich in flowers) and 'kruidenrijke akkers' (plots rich in herbs) in the Netherlands. Associated breeds/varieties are generally regional breeds/varieties that are adapted to local circumstances. By selecting low production environments one avoids that the indicators are dominated by the few (globally) dominant high production breeds which are adapted to high production environments. Instead of number of individuals it is better to use the number of breeding males for livestock. This number is generally available and reflects more closely the effective population size than the number of individuals.

Other issues

In the case of all these indicators, policy interest centres around changes in these indicators over time. This implies setting an appropriate interval for measurement. Little has been discussed in this area but given the timeframes of breeding and subsequent diffusion processes, it is probably most appropriate to consider a certain number of years (e.g. five). For indicators that may exhibit greater fluctuations, the use of moving averages can be helpful in portraying trends, though this may require more frequent data.

To discuss indicators, it is necessary to relate them to some explicit geographical scale. Even if one discusses temporal diversity, some scale must be applicable. Geographical scale, in the case of agriculture then carries some connotation of production systems.

Given lack of knowledge, it may be useful to have indicators of state of current understanding, or alternatively gaps in understanding, concerning genetic diversity.

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4 The two indicators were the remaining area of nature; and the number of individuals of species, which are characteristic for specific ecosystems.

Extended set of indicators

Incorporating the proposed additional indicators into the set of Wetterich leads to an extended set of indicators shown in Table 2. This set of indicators captures both actual diversity and the processes of table 1 (pressure-state-response framework) influencing biodiversity.

Table 2. Extended set of indicators.

Livestock	Crops	Source[a]
• Average size of farms	• Average size of farms	this paper
- area in ha	- area in ha	"
- number of animals	- kg crop produced	"
- animals / ha	- kg / ha	"
	• No. of crop species in use	Wetterich
	• Crop species ratio/diversity index	"
• Number of key livestock breeds	• No. of registered key crop varieties	OECD
- native endangered	- domestic	"
- native not endangered		"
- non-native	- non-domestic	"
• Share of the three major livestock breeds	• Share of the three major crop varieties in seed production area / diversity index	"
- native/ non-native		
• Population size native breeds	• No. of endangered crop varieties	"
- status of endangerment		"
- no of. breeds conserved in situ		this paper
• No. of breeds conserved *ex situ*	• No. of breeds conserved *ex situ*	"
• No. of accessions characterised	• No. of accessions characterised	"
• Intensification and use of modern breeding strategies	• Intensification and use of modern breeding strategies	"
• Application of high-selective breeding methods (such as embryo transfer)	• Percentage of seeds originating from own farm	"
• Number of breeding males of breeds characteristic for landscapes/production environments important for biodiversity and /or characteristic for a region or country	• Share of crop varieties and species adapted to landscapes/production environments important for biodiversity and /or characteristic for a region or country	"
	• area of low production/high biodiversity	"
• No. of breeders associations per breed	• No. of breeders / crop	Wetterich
• No. of different breeding goals	• No. of different breeding goals	this paper

Notes
[a] No attempt is made here to identify the original source or proposer of the indicators in the table, which may in many cases not even be possible. Here ‘source’ refers primarily to the lists of indicators as covered in the text.

There is, however, one drawback of this extended list. In total 7 indicators are listed for livestock and 12 for crops, most indicators being subdivided. This large number makes them less useful for a quick and easy to interpret assessment of the state of agricultural biodiversity. This is one reason why for wild species only two indicators are proposed. Therefore we also propose a restricted set of indicators.

Restricted set

A restricted set of indicators should provide in a single glance the state of agro-biodiversity. The level of detail and information of the extended set can never be achieved, in the restricted set, yet a good overview must be possible. Two indicators of the extended set can be used for this purpose:

- Number of breeding males (livestock) or crop area of breeds/varieties characteristic for landscapes/production environments important for biodiversity and characteristic for a region or country.
- Area of low production/high biodiversity agriculture

These indicators run parallel with the two similar indicators proposed for wild species, and capture most of the agro-biodiversity and processes influencing agro-biodiversity. Additionally they also capture the link between agriculture and biodiversity of wild species. Of course they do not capture the whole picture. Two areas of agro-biodiversity in particular are missing: diversity of high production breeds/varieties and ex situ conservation. So, the proposed indicators above can be supplemented with two indicators for livestock:

- Number of breeding organisations of high production breeds
- Number of breeding males in gene bank(s) of characteristic (low production) breeds

and for crops:

- Percentage seed originating on farm of three major (high production) breeds
- Number of characteristic (low production) varieties stored in gene bank.

Originally we entered the number of breeding males of the three major (high production) breeds in the restricted set, but information for this indicator proved to be very difficult to gather (see under case studies) so that it was replaced by the number of breeding organisations. Table 3 sums up the indicators in the restricted set.

Table 3. Restricted set of indicators.

Livestock	Crops
Number of breeding males of breeds characteristic for landscapes/production environments important for biodiversity and characteristic for a region or country	Area of varieties characteristic for landscapes/ production environments important for biodiversity and characteristic for a region or country
	Area of low production/high biodiversity agriculture
Number of breeding organisations of high production breeds	Percentage seed originating on farm of three major (high production) breeds
Number of breeding males in gene bank(s) of characteristic (low production) breeds	Number of characteristic (low production) varieties stored in gene bank

Latent diversity

Almost all of the indicators discussed up until this point are based on measures of apparent diversity. Indicators of latent diversity, or diversity measured at DNA level, have been proposed but mostly in research studies. Genetic diversity at the molecular level is called polymorphism.[5] Diversity at the molecular level is the most important from a scientific perspective but is expensive to measure as it is not based on observable, or apparent, differences as embodied in the classification of animal breeds and crop varieties. There is also the question of which part of the genome should be sampled for polymorphisms. One issue is that not all polymorphisms are equally important. Polymorphisms in functional genes may directly influence important traits such as growth or health, while other

5 Polymorphism is the simultaneous and regular occurrence in the same population of two or more discontinuous variants or genotypes in frequences which cannot be accounted for by recurrent mutation (Ford, 1940). Polymorphism may be used as an indicator of evolutionary potential of a given population, the characteristic of interest for conservation purposes, but the relationship between polymorphism and evolutionary potential is not that direct (Meng *et al.*, 1998).

polymorphisms are neutral in effect. One can argue that for this reason only polymorphisms in functional genes such as the MLHC-locus should be sampled. However, traits considered important today may be different from what is considered important in the future, which is precisely one of the reasons why old breeds should be conserved.

The way around this dilemma is not to sample polymorphisms in functional genes, but to use an indicator for diversity of the whole genome. If the pedigree is available one can calculate the proportion of the genome that two individuals have in common through descent. This is the same as the probability that two alleles of a gene are identical by descent, which is known as the relationship coefficient, which is twice the coancestry or coefficient of parentage (COP) (Falconer 1989). Meng *et al*. (1998) also refer to pedigree analysis as an additional approach to measuring latent animal or crop diversity.[6] Pedigree analysis, which has been applied in a number of studies, is conducted using genealogical information about the parentage of a variety. A variety of methods and indices have been developed for pedigree analysis. One of these is 'pedigree complexity' which includes specific details about numbers and origins of landraces in a variety's ancestry or the number of breeding generations since the first cross. Specific indices that have been used include the numbers of distinct parental combinations and numbers of unique landrace ancestors per pedigree (Smale & McBride, 1996; Hartell, 1996). Another method entails calculating the COP for every possible pair of varieties/breeds within a given group.[7] COPs have been widely used in studies of change in genetic diversity, perhaps because of the general availability of genealogical information (e.g. van Hintum & Haalman, 1994; Souza & Sorrells, 1991).

A major limitation of COPs as an indicator of latent genetic diversity for policy purposes related to conservation, concerns diversity among traditional breeds or landraces. The parentage of such breeds or landraces is not known and more complex. Meng *et al*. (1998) describe this and a number of other simplifying assumptions employed in the calculation of COPs which have been reason for criticism. More promise may be offered by using molecular methods to test the degree of relatedness among such varieties, and to assess the genetic contributions according to various ancestors.

In the absence of a pedigree relationship coefficients or COPs can be estimated with the help of neutral markers, provided that we sample enough markers across the genome. One problem to be solved is that markers can also be alike in state without having a common descent. Eding (2002) has developed a method to do this correctly called marker estimated kinships (MEK). The average kinship within a group of individuals is inversely related to its diversity, because the more genes they have in common the less genetic diversity. The same applies across groups, a low average kinship between two breeds, varieties, populations etc. implies that the two groups are genetically diverse.

Several important issues arise from Eding (2002)'s research on MEK:

- by using (average) kinship estimates, diversity is measured reliably in a way that directly relates to the approach of breeders
- one can form a core set of breeds/ varieties in such a way that most of the diversity of a species is captured in the core set and that diversity in the core set will increase only marginally if an extra species is added to the core set
- by defining a 'safe set', i.e. the set of, generally high production, breeds/ varieties that is dominating agriculture, as the starting point one can estimate what amount of diversity each breed/ variety adds to the secure part of diversity within a species.

Eding's research concentrated on livestock data but similar approaches to defining 'core sets' of crop varieties are being developed for gene banks (van Hintum & Haalman, 1994).

Molecular methods have the advantage of providing some sort of measure of the genetic difference, or 'distance' between elements in a population. These measures can be used to calculate an index of diversity among the population in question. Two such indices have been proposed and applied by Weitzman (1992, 1993), and Solow & Polasky (1994). Genetic distances, however, tend to favour the conservation of less diverse inbred breeds or

6 Pedigree analysis is however ultimately based on units defined according to apparent diversity: breeds and varieties.

7 The complement to the coefficient of parentage (COP) is the coefficient of diversity (COD = 1 – COP).

varieties over breeds or varieties that harbour large amounts of genetic diversity. Eding (2002) improved Weitzman's index (see above) and applied it to populations of African cattle.

Despite difficulties and costs, it is important to make some attempt to develop further approaches to monitoring latent diversity, in addition to apparent diversity. There are enough instances of two crop varieties displaying morphological differences that hide the underlying genetic similarity (Dudley, 1994).[8] The share of genetically heterogeneous and homogeneous varieties of crop varieties and the evolutionary potential in the proposed extended set can be seen as proxy indicators for latent diversity. The number of males per breed also provides a proxy indication of latent diversity in these breeds. Latent diversity will continue to be the subject of research. In particular, further investigation of the circumstances under which latent diversity is reasonably represented with indicators of apparent diversity, or other proxy indicators, could be quite useful from a policy perspective.

[8] Cited by Meng *et al.* (1998).

4. Case studies

This section contains the results of case studies in which the various sets of indicators are applied for one livestock species and one crop species. Availability of data and the state of biodiversity is likely to differ widely between Western and developing countries, but indicator sets have to perform well under both circumstances. Therefore the case studies have been undertaken in two countries for both crops and livestock, the Netherlands and either a developing country or an economy in transition.

For animals chicken was chosen because chicken is an important species in both industrialized and developing countries, chicken is important for both the commercial sector and for hobby breeders. Moreover, a study on genetic diversity at the DNA level (latent diversity) in the Netherlands was available, so that indicators could be matched against latent diversity. Vietnam was chosen because it is close to the origin of the chicken, because chicken form an important part of the meat consumption in Vietnam, and because of existing contacts with Hanoi Agricultural University.

Wheat was chosen for the plant case study because of its importance in a large number of countries around the world. This also means that a fair amount of data is available on wheat diversity, also because breeding of wheat has been primarily undertaken by public research institutes. The second wheat case study was performed for China.

For the Vietnamese chicken study first data were collected by Vietnamese scientists and then the report was compiled by a visit of a Dutch scientist to Vietnam. The Chinese study was performed more at a distance, where Chinese scientists collected data and a Dutch scientist compiled the report in the Netherlands through contacts by e-mail etc. In this way we could also compare the indicator sets compiled with intensive collaboration or through loose contacts.

4.1 Chicken

General description of chicken diversity in developed and developing countries

Nowadays the world market is dominated by a few breeding companies: for layers these are Hendrix (Nutreco), Lohman/Hyline (Aviagen) and Hubbard/ISA (Merial) and for broilers Ross Breeders (Aviagen), Cobb-Vantress, Hubbard/ ISA (Merial) and Hybro (Nutreco). The products of these companies dominate in the Netherlands (Kaal, 2002) and are also present in Vietnam. In the Netherlands in the past century local breeds have lost their economic importance and are now maintained by small breed organizations, often in the form of fancy breeds. Thus there has been a shift from local, often regional breeds to a few commercial lines which are marketed at a world wide scale. In Vietnam chicken of local origin are still dominating, although some local breeds are threatened.

4.1.1 Chicken diversity in the Netherlands

CBD indicator

- Total number of livestock breeds

Currently there is a large number of different breeds in the Netherlands including many exotic breeds. Many breeds occur in two forms, the standard form and the dwarf-form (bantam or in Dutch 'krielen'). There are collections from 112 non-commercial breeds (or 189 if dwarf-forms are counted as separate breeds) listed on the website of the CBD Netherlands focal point for access and benefit sharing (www.absfocalpoint.nl, see also www.kippenrassen.nl). It is not clear whether some breeds that do occur in the Netherlands may have been missed. What is clear is that apart from the 20 breeds of Dutch origin a large number of exotic breeds is present in the Netherlands.

The commercial layers consist of crosses of White Leghorn lines and Rhode Island Red lines, while commercial broilers consist of White Plymouth Rock lines and White Cornish lines (Kaal, 2002). A breed in the traditional sense, where groups of breeders form an organisation that guards the standard of the breed, does not exist for these commercial chicken. The important unit for the commercial chickens is not the breed but the line. Poultry breeding is organised in a pyramid like structure. At the top, each company breeds a limited number of pure lines. Grand-parent farms receive material from the companies and cross these lines. The resulting crosses are crossed again with other crosses at parent-farms. The end result at the bottom of the pyramid is thus a cross of four lines and these crosses are used for the production of eggs and broilers for the consumer market. There are 41 different four-way layer crosses available and 32 for broilers (Kaal, 2002).

To sum up there are, currently, at least 116 breeds (4 commercial and 112 other) in the Netherlands. If dwarf forms are counted as separate breeds and for commercial chicken four-way-crosses are counted instead of breeds the number is at least 270 breeds. This is most likely a considerable increase compared to the number of breeds that were present in the Netherlands around 1950, since around that time exotic fancy breeds were rare.

Using this indicator the situation for the biodiversity of chicken in the Netherlands thus seems flourishing, which is in contrast with the general feeling that the domination by a few breeds of world wide operating companies has lead to a strong reduction in biodiversity.

OECD indicators

The OECD set contains three indicators for livestock species:

- Total number of livestock breeds registered and/or certified for marketing

With respect to the first indicator there are 73 commercial four-way-crosses available for marketing from 4 breeds (see above). Furthermore there are 20 indigenous breeds recognised by the Dutch rare breeds society (SZH), or if dwarf-forms are counted as separate breeds 35 breeds.

- Share of key livestock breeds in total livestock population

With respect to this indicator there are about 50,000,000 broilers and about 44,000,000 layer hens in the Netherlands. The number of animals on parent-farms and grand-parent farms, thus the breeding animals, is about 12,000,000 for layers hens and not known for broilers, but probably in the same order (Kaal, 2002). For the indigeneous breeds the number of breeding animals is about 12,000 (Boks & Hans, 2002). There are a considerable number of chicken in the Netherlands that fall outside the official statistics. Many chicken are kept as pets and do not belong to a particular breed. This number is not precisely known but estimated to be about 75,000 to 100,000.

If we ignore chicken outside official statistics and only consider the breeding animals the share of the key breeds (about 24.000.000) is just above 99.95%. If we take all animals into account, including animals outside parent farms and animals kept as pets the share of the key breeds is about 99.89%.

- The number and share of national livestock breeds that are endangered

Table 4 shows the number of breeding animals for national livestock breeds. These numbers concern only the animals present in the Netherlands. It can be seen that most breeds can be considered endangered. Only three breeds (Fries Hoen, Hollandse Kriel and Sabelpootkriel) consist of more than 1000 breeding animals. The share of each breed is well below 0.01% (see above under 2nd OECD indicator).

Table 4. Population size and number of breeders of Dutch chicken breeds (source Boks and Hans, 2002).

	Large			Krielen		
Breed	No. breeding animals	No. Breeding males	No. breeders	No. breeding animals	No. breeding males	No. breeders
Brabanter	225	75	10	185	60	8
Kraaikop	140	40	13	50	15	5
Uilebaard	300	100	13	225	75	10
Hollands Kuifhoen	160	35	10	200	50	15
Baard-kuifhoen	105	30	8	165	40	15
Groninger Meeuw	800	150	20	235	60	15
Fries Hoen	1100	300	100	650	200	60
Drents Hoen	225	75	35	270	70	35
Lakenvelder	200	50	30	230	60	30
Hollands Hoen	175	50	30	200	50	20
Twents Hoen	?	?	?	?	?	?
Welsumer	330	80	40	550	150	65
Barnevelder	515	115	50	400	100	40
N. Hollands Hoen	300	50	45	110	30	20
Assendelfter	135	35	20	110	20	10
Chaams Hoen	150	50	20	-	-	-
Schijndelaar	50	10	2	-	-	-
Hollandse Kriel	-	-	-	>1000	>1000	>200
Sabelpoot-kriel	-	-	-	1380	540	100
Eikenburger Kriel	-	-	-	25	7	5

Extended set

- Average size of farms

There are, apart from breeding farms, about 2, 200 farms with a total of 31 million layers and 1,225 farms with a total of 53 million broilers (Kaal, 2002). This gives an average number of about 14,000 layers and 44,000 broilers per farm. The 200 largest farm have about 80,000 – 85,000 animals on average, both for broilers and for layers. Generally the chickens are not free ranging, so the number of animals/ ha is not interesting. The indigenous breeds are at the other end of the range; average number of animals per owner/breeder/farm is in the range of 10 to 15 animals.

- Number of key livestock breeds (native endangered, native not endangered, non-native)
- Share of the 3 major livestock breeds (native, non native)
  - Number of breeding males of the three major (high production) breeds

The number of breeding males in the high production breeds is a trade secret. Breeding of the high performance lines is organised in a pyramid structure, where eggs from the pure lines bred by the breeding organisations is crossed and multiplied in grand-parent farms, which in turn supply eggs to parent-farms, which again cross and multiply the crosses from the grand parent farms. For the layers the size of grand-parent farms is a total of 750,000 animals. However, this tells us nothing about the effective population size maintained.

- Population size of native breed (status of endangerment, no. conserved in-situ)

These indicators are largely covered by the OECD indicators. With respect to the status of endangerment all indigenous breeds, except the 'Hollandse Kriel' and 'Fries Hoen', can be considered endangered or vulnerable (FAO-criteria).

- No. of breeds conserved ex-situ
- No. of accessions characterised

In the national Dutch gene bank sperm of 11 indigenous breeds is stored (www.cgn.wur.nl/angr, last visited 17 March 2006). These breeds were chosen on the basis of their genetic uniqueness (see latent diversity) and taking into account whether (related) breeds occur outside the Netherlands. 7,699 doses of semen of 119 males of 11 breeds are stored in the Dutch gene bank and all males and semen doses are characterized.

- Intensification and use of modern breeding strategies

High selective breeding strategies are used for all commercial high performance lines. Which strategies are used exactly (e.g. use of QTL/marker assisted selection) and how much attention is paid to inbreeding is a trade secret and figures are not available.

- Number of breeding males of breeds characteristic for landscapes or production environments important for biodiversity and characteristic for a region or country.

Of the breeds in table 2 there are a number that can be regarded as typical Dutch which are characteristic for specific regions. The following is based for a large part on descriptions of the rare breed society in the Netherlands (SZH, website Archeological finds indicate that chicken already occurred in the Northern part of the Netherlands (Friesland) at least about 2000 years ago. Similar types of chicken occurred along the coast from Northern France till Northern Germany. This group developed into several regional breeds. Breeds that belong to this group are the French 'Poule de Bresse' and the German Ost-Friesian Meeuw. In the Netherlands the 'Assendelfter, Chaams Hoen, Brabanter, Fries Hoen, Drents Hoen and Groninger Meeuw' all belong to this group. Any of these breeds could have been selected as a representative indicator species for biodiversity, but we selected the 'Groninger Meeuw'.

Figure 2. De 'Groninger Meeuw' local breed of the North Eastern province Groningen in the Netherlands.

De 'Groninger Meeuw' (http://www.szh.nl/rassen/hoenders/groningermeeuw/algemeen.html) is the local breed of the North Eastern province Groningen in the Netherlands. The black dots (so called 'pellen') on the feathers are characteristic for the hens, and also occur in related breeds. Around 1900 it used to a be rather common chicken breed, generally free ranging on the yards of farms. Since then it decreased in numbers until 1975, at which time it was almost extinct. In 1975 a few breeders started a program of recovery, and since then the breed can be seen at poultry shows. The numbers have now risen to about 800 of which 150 breeding males, while the number of breeders are around 20. A challenge for the future is to re-establish the breed as a layer, and not just a show breed.

Taken as an indicator species the conclusion from the history of the Groninger Meeuw is that biodiversity has disappeared to a large extent, but not completely. Its fate is now largely in the hands of a few amateur breeders, and it does not have a commercial value as a production animal. All this agrees largely with the picture of all the indigenous breeds taken together.

- No. of breeders/breed associations per breed

World wide four breeding companies for high performance breeds remain. This is a strong reduction. For the indigenous breeds there is one breed society per breed. The number of breeders per breed is on average about 30 and varies from 2 (Schijndelaar) to >200 for the Hollandse Kriel (Boks & Hans, 2002). There seems to be a slow but steady decrease in the number of breeders of indigenous breeds.

- Number of breeding goals

The main breeding goal trait for the high performance breed is number of eggs for layers and growth rate for broilers. Breeding companies do not give specific information on their breeding goals and breeding strategies. It is, however, clear that in recent years there is increasing attention for robustness. Currently separate crosses for organic farming do not exist. The indigenous breeds are mainly bred as fancy breeds and the main breeding goal is the breed standard. In most breeds there is considerable variation in colour forms (kleurslagen), and many breeders specialise in one or two forms.

Restricted set

- Number of males of breeds characteristic for landscapes or production environments important for biodiversity and characteristic for a region or country.

see extended set

- Number of breeding organisations for high production breeds

World wide four breeding companies for high performance breeds remain, and all four are active in the Netherlands.

- Number of breeding males in gene bank(s) of characteristic breeds

In the national Dutch gene bank sperm of 11 indigenous breeds is stored. These breeds were chosen on the basis of their genetic uniqueness (see latent diversity) and taking into account whether (the same or related) breeds occur outside the Netherlands.

Latent diversity

An extensive survey of latent diversity in Dutch chicken breeds was performed by Eding *et al.* (2003). Genetic diversity was estimated based on 17 micro-satellite markers across the genome, with number of alleles per marker varying from 6 to 26. Eighteen indigenous breeds, 2 exotic breeds and 26 commercial lines from high performance breeds were investigated.
Breeds and lines were clustered based on the kinships estimated from the data. The two exotic breeds (Bankiva and Sumatra) formed two separate clusters while all other (Western) breeds formed a third cluster. Within this third cluster three indigenous breeds (Drents, Hollandse Kriel and Kraaienkop) formed separate clusters. The remaining cluster consisted of four clusters: white layers, brown layers, broilers and other indigenous breeds. The Barnevelder

and Noordhollands hoen were included in the white layers and the Welsummer in the broiler cluster. Thus most indigenous breeds have a separate position from the high performance lines.
The contribution of indigenous breeds to the total genetic diversity could be quantified more precisely. The optimal core set, i.e. the set of breeds that captures most of the genetic variation with the least overlap between the breeds, consists of 3 broiler lines, 3 layer lines, 7 indigenous breeds and one exotic breed. When only high performance lines (the ‘safe set’) are considered 4.5% of the genetic diversity and 39.25% of founder genome equivalents would be lost (these numbers are relative to a founder population in which all genetic variation of todays breeds is represented). Adding a single breed to this safe set could reduce this loss to 2% and 22.9% respectively. Thus one can conclude that the high performance lines are genetically quite diverse, but that the small indigenous breeds still harbour considerable amounts of genetic diversity that is not present in the high performance lines. Many of the indigenous breeds are inbred, which is not surprising given their small population sizes. It is thus remarkable that they still harbour considerable amounts of genetic diversity. However it is not possible to quantify the loss of genetic diversity that has occurred in the past, without samples from the past. Probably this loss has been considerable given the small current population sizes.

Conclusion

All indicators, except the CBD indicator ‘number of breeds’ indicate that genetic diversity of chicken in the Netherlands is reduced. It is clear that indigenous breeds are marginal in numbers and that the commercial breeds dominate in the Netherlands. It was not possible to find information on all indicators. Especially indicators involving biodiversity management of commercial lines are not available. The breeding companies operate on a world wide scale, which raises the question whether indicators on a national scale are appropriate. Information on the indicators in the past is also hard to come by.

4.1.2 Chicken diversity in Vietnam

CBD indicator

- Total number of livestock breeds

A total of at least 28 breeds, of which 15 are native, are present in Vietnam (Ly *et al.*, 2001, Ministry of agriculture and rural development 2004). More breeds may be present as Vietnam is a large country and localized breeds may have been missed up to know. Recently two such local breeds have been discovered. Millions of households have several scavenging chicken. These do not belong to a specific breed in the sense that they are not bred by organisations such as herd books or local breeders with specific breeding goals and breed standards. Further on these chicken are referred to as the Ri breed, but one should keep in mind it is a highly diverse assembly of indigenous Vietnamese chicken. The number of breeds probably increased somewhat due to the introduction of foreign breeds, although four of these have disappeared again.

OECD indicators

- Total number of livestock breeds registered and/or certified for marketing

There are 9 registered breeds in Vietnam. These are all breeds for high production systems. Local breeds for scavenging are not registered.

- Share of key livestock breeds in total livestock population

The key-breeds/varieties referred to in the second indicator are the dominant breed/varieties in terms of production. In Vietnam the dominant breed in numbers is the Ri breed. This is the Vietnamese chicken that is abundant throughout the country. They are scavengers and almost every household in the countryside have a few of these chicken. Of the 166.6 million chicken (2003 statistic) in Vietnam about 65-70% belong to the Ri breed. It is, however, not comparable to the high production breeds in Western countries that this indicator originally refers to. The share of industrial chicken production, generally in the form of cross breeds, in Vietnam is about 20%. The number of chicken decreased in 2004 to 159 million because of avian influenza. This decrease mainly affected the industrial high production breeds.

- The number and share of national livestock breeds that are endangered

In Table 5 the native Vietnamese chicken breeds are listed. Of the 14 breeds 9 can be considered endangered and 1 vulnerable. Thus 71% of the breeds are threatened. However, for most of the breeds a conservation programme is in place that ensures the survival of the breeds. This is done by subsidising families that keep the breed, by ex situ conservation of breeds at the National Institute of Animal Husbandry (NIAH) in Hanoi, and by facilities for conservation of DNA-samples.

Table 5. Population size and number of breeders of native Vietnamese chicken breeds (source Ly et al., 2001; Ministry of agriculture and rural development 2004; National Institute of Animal Husbandry 2004; and own research).

Vietnamese name	English name	No. breeding animals	No. Breeding Males	No. breeders*	Ex situ population	Endangered
Gà Ri	Ri chicken	12,500,000	1,200,000	>2.5 million	No	No
Gà Ho	Ho chicken	360	40	21	No	Yes**
Gà Mía	Mia chicken	400	80	5	Yes	Yes**
Gà Dong Tao (Cao)	Dong Tao chicken	350	60	12	Yes	Yes**
Gà Ác	Silky chicken	600	180	30 + 1	Yes	No
Gà H'Mông	H' Mong chicken	1500	250	2 org.	Yes	Vulnerable
Gà Lun (Te)	Short leg chicken	600	190	30 + 1	Yes	Yes**
Gà Tau váng	Yellow Chinese chicken	100,000	20,000	20 + 1	No	No
Gà Tre	Bamboo chicken	1600	300	30 + 1	No	Yes**
Gà Choi	Fighting chicken	600	150	?	No	No
Gà To ***	To chicken	22	4	1	No	Critical
Gà Mong	Mong chicken	500	100	14	No	Yes**
Gà Oke	Black chicken	600	140	?	No	Yes
Gà Dán Khao***	Six toes chicken	20	?	?	No	Critical?
Gà Van phú	Van phu chicken	0	0	0	No	extinct

* *No. breeders refers to families that breed the chicken, if two numbers are mentioned the second number refers to breeding organisations (Generally the NIAH, National Institute for Agriculture, Hanoi).*
** *In national conservation program, so that extinction is prevented*
*** *Only recently discovered*

Extended set

- Average size of farms

According to the official statistics there are almost 3 million farms with chicken in Vietnam. The average size is 0.19 ha with on average 57 animals. Farms tend to be larger in the south. The husbandry systems can be divided in scavenging on family farms, semi scavenging with so called garden chicken, where chicken receive additional food next to the scavenging, and industrial systems of the intensive producers. On industrial farms on average almost 21300 chickens are held, farms with garden chicken just over 250 chicken and family farms about 27 chicken.

Outside the official statistics are farms or rural households with just a few chickens. Most households outside the cities have chicken, although generally the main source of income lies elsewhere. A rough estimate is that of the 16 million rural households (almost 74% of the Vietnamese population) 95% have chicken, which results in about 15.2 million households with chicken. These households have on average about 4 or 5 animals.

- Number of key livestock breeds (native endangered, native not endangered, non-native)
- Share of the 3 major livestock breeds (native, non native)

Population size of native breed (status of endangerment, no. conserved in-situ)

These indicators are largely covered by the OECD indicators in so far native breeds are concerned. In table 6 the situation for the non-native breeds is given. These breeds are either used in semi scavenging systems or industrial systems. A number of these breeds are declining. In part this is because with the change to an open market economy better high performing breeds are available nowadays. Another reason is that the western high production breeds often do not cater for the Vietnamese taste. In Vietnam brown eggs with dark yolks are preferred, and the meat should be firm. The large and tender breast filets of western breeds are not popular. This explains the success of the cross breds of Sasso and Kabir with the Luong Pho chicken from China in semi scavenging systems. These cross breds are now next to the Ri breed the most common chicken in Vietnam. Recently the industrial breeds have suffered badly from Aviary Influenza, causing a decline of over 16%.

Table 6. Population size and number of breeders of non-native chicken breeds in Vietnam (source …).

Name	Origin	No. breeding animals	No. Breeding males	No. breeders	Use
Rhode Ri	Vietnam/USA hybrid	1,000	120	1	Declining
Tam Hoang	China	10,000	1,300	2	Garden chicken
Luong Phuong	China	500,000	62,500	5	Mother line for garden chicken
Kabir	Israel	100,000	14,900	3	Father line for garden chicken
Hy – line	USA	500,000	55,200	5*	Industrial, laying
Sasso	France	100,000	15,000	3*	Father line for garden chicken
AA (Abor acres)	USA	100,000	16,000	5*	Industrial, meat
ISA (line MPK)	France	100,000	15,400	1	Industrial, meat
Leghorn	England	100	20	1	Replaced
Ross 208	Italy via Cuba	10,000	1,560	1	Replaced
Transylvanian Naked Neck	Hungary	75	14	1	Research
Hungarian Yellow	Hungary	24	5	1	Research

** Only one world wide operating breeding company, but several companies market parent stocks*

- No. of breeds conserved ex-situ

There are five endangered breeds for which a population is kept ex-situ for conservation by the National Institute of Animal Husbandry (Table 5). There is also a yellow Ri line kept for the same purpose. No sperm is stored in a gene bank. Currently only blood samples for DNA analysis are stored for eight breeds. In the future cryo-preservation of sperm might be developed, as the technology for freezing sperm of cattle is already present in Vietnam.

- No. of accessions characterised

A total of 219 blood samples (20 to 50 per breed) are characterized and stored for possible DNA typing.

- Intensification and use of modern breeding strategies.

These are only used in the high production breeds (see under the case study in the Netherlands).

- Number of breeding males of breeds characteristic for landscapes or production environments important for biodiversity and characteristic for a region or country.

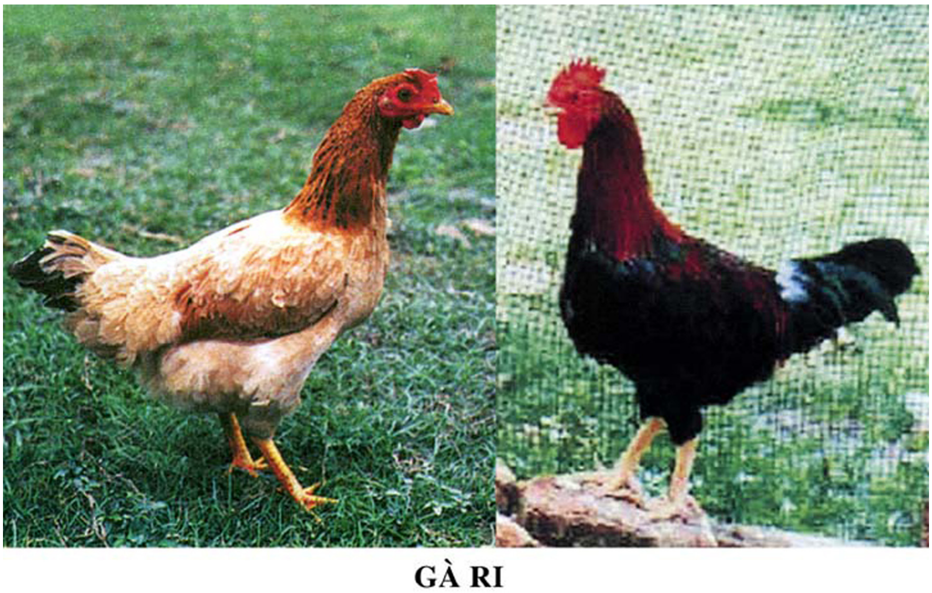


Figure 3. *Ri chicken. The local household chicken of Vietnam.*

The breed characteristic for low input systems in Vietnam is the Ri chicken. This is not a breed in the sense that it has a clearly defined breed standard. It is more an assembly of all scavenging chicken that are typical of household farms across Vietnam. It is a relatively small chicken with several colours. The predominant colour in females is yellow, including the beak and legs. Males are predominantly dark red with greenish black wings and tails. About 65 70% of the chicken in Vietnam are Ri chicken and the numbers are stable. The breed is not replaced by high input/high production breeds because the meat is considered a delicacy, not matched by any foreign high input breed. Moreover, they are easy to hold, need no special chicken feed and are fairly resistant. The only threat in the future might be urbanisation and the consequent loss of small household farms.

Figure 4. *Ho chicken. Endangered breed of the village Ho.*

Although the Ri breed probably reflects to a large extent the state of diversity in Vietnamese chicken, it is not representative for the development of all native low input breeds in Vietnam. The Ho chicken may be taken as an example of local breeds with small population sizes. It is confined to a few neighbouring villages in the North of Vietnam. It has strongly decreased, mainly because of poor reproduction (late maturity and low egg yields) It is a very large chicken (around 4kg) and (consequently) the hens are poor mothers, often destroying their eggs or killing their chicks by accident with their large legs. In its favour is that it is well adapted to scavenging and resistant to diseases, and provides once mature abundant and delicious meat. In the past the meat was produced for the courts of kings and mandarins. However, today an individual chicken is too large for the average Vietnamese family, and not easily sold on the regular markets. The decline was halted by a special government program installed to conserve rare breeds. Under this program local farmers receive subsidies for keeping special breeds. Still more measures such as the acquisition of egg incubators is desired. Since the start of the program numbers have started to increase again. It will, however, remain vulnerable, because it is very localized, relatively close to Hanoi, and consequently sensitive to urbanization of that region.

- No. of breeders/breed associations per breed

See table 5 and 6.

- Number of breeding goals

Breeding goals are different between breeds. In high production breeds the main breeding goal trait is either number of eggs for layers or growth rate and size at maturity for broilers. The scavenging and semi scavenging breeds are generally dual purpose breeds. Several breeds have non food breeding goals. The Ho chicken is also bred for cultural reasons as they are linked to the heritage of Dong Ho paintings. The Ac breed is used for medical purposes as they are considered to have health improving and healing properties. The Tre breed are bred as pets and the Choi are bred for cock fighting. The Oke breed is bred for black meat.

Restricted set

- Number of breeding males of breeds characteristic for landscapes or production environments important for biodiversity and characteristic for a region or country.

See under extended set.

- Number of breeding organisations for high production breeds

World wide four breeding companies for high performance breeds remain. All four are active in Vietnam, though represented by several companies marketing parent stocks (see table 6).

- Number of breeding males in gene bank(s) of characteristic breeds

No sperm of males have been stored in a gene bank yet.

4.2 Wheat

The genus wheat (latin name *Triticum L.*) consists of several species. The case studies are confined to the wheat that is most commonly cultivated, baking wheat (*Triticum aestivum*) which is used for bread and is a hexaploid species. Other species, like the durum wheat (*Triticum durum* Desf.) which is used for noodle production and is tetraploid are not considered.

4.2.1 Wheat diversity in the Netherlands

During the last two decades approximately 130,000 hectares of wheat are annually cultivated in the Netherlands. On average this is 68% of the total area of cereals that are grown in the Netherlands. Other cereals that are grown in Dutch agriculture are Barley (spring and winter), Rye, Oats and Triticale.
Over the years 1992-2003 cereals are grown on approximately 18,000 farms each year. Of these farms, the majority only grows crops (67%), followed by raising cattle (22%) and combinations of both (11%) (CBS, Statline; www.cbs.nl).

For wheat, especially winter wheat is grown in the Netherlands. During the period 1980-2003 the annual area with wheat consists for 89% of winter and for 11% of spring wheat. Sowing winter wheat has preference above spring wheat until mid-December. After that date, and especially after January, the chance of a good crop for winter wheat decreases and spring wheat is generally more preferred.
Depending on the requirements of the processing industry breeds of spring and winter wheat are categorized into several types:

- wheat with better baking quality
- baking wheat
- wheat with a quality intermediate between baking and fodder wheat and used in mixtures with wheat of better baking quality
- fodder wheat
- other wheat

The Variety List of Field Crops is published annually (since 1924) and includes the National List and the Recommended List of varieties. The National List includes all the varieties registered in the Netherlands having sufficient value for cultivation and use according to European Union standards while the Recommended List includes a selection of varieties that are considered to be of special interest for Dutch agriculture. These selected varieties should have sufficient value for cultivation and use. In the Variety List of Field Crops also the different spring and winter wheat varieties with sufficient value for cultivation and/or of special interest for Dutch agriculture are included.

Varieties that are included in the National List and that have entered (based on an assessment of distinctness, uniformity and stability) the Dutch Register of Varieties may be commercialized in the Netherlands. Also, varieties that are included in the Common Catalogue of Agricultural Crops of the European Union are free to be commercialized in the Netherlands (as well as into other countries throughout the European Union). Of these certified varieties, only a selection is described and considered of special interest for the Dutch agriculture. These varieties are included in the Recommended List.

Until 1992 the relative importance of the different varieties included in the Variety List of Field Crops is monitored and included in this list. For obtaining insight in the relative importance of varieties in the list for more recent years, data from the Dutch General Inspection Service (NAK) on certification of areas for seed production have been used. Thereby, the assumption is made that all produced seeds are used for the cultivation of wheat in the Netherlands.

CBD indicator

- Total number and share of main crop varieties

The CBD indicator for plant varieties is the total number of varieties. From the data obtained from the Dutch General Inspection Service it follows that in the years 2002, 2003 and 2004 the number of 'varieties' included in table below are included in the production of seeds for winter and spring wheat. For some of the 'varieties' listed in the data of the Dutch General Inspection Service it is unclear whether they point to varieties or research material for which seeds are produced in the particular year

Table 7. Total number of wheat varieties in the Netherlands listed on the national list and total share of these varieties.

	2002		2003		2004	
	# varieties	share (%)	# varieties	share (%)	# varieties	share (%)
Winter wheat						
on National List	21	85	25	90	26	87
not on National List	36	15	31	10	25	13
Spring wheat						
on National List	9	92	9	91	10	87
not on National List	2	8	3	9	5	13

Data from the Variety List of Field Crops and the Dutch Inspection Service (NAK).

The share of different varieties in the Dutch agriculture is obtained with data on the certification of seed production from the Dutch Inspection Service (NAK). The last three years, for winter wheat 85-90% of the area was cultivated with varieties from the National List. For spring wheat the share of varieties from the National List was 87-92% over the same years. For winter wheat two main crop varieties (Drifter and Residence) can be recognized which each account for 20% of the area. For spring wheat Baldus and Pasteur accounted for more than half of the area in 2002 and 2003 . In 2004 more than half of the area was accounted for by Pasteur and Tybalt.

OECD indicators

- Number of registered and/or certified crop varieties for marketing

The number of varieties on the Descriptive List of Field Crops in 1950 was 13 for winter wheat and five for spring wheat. Also there were two varieties of intermediate wheat placed on this list. These numbers are smaller than the number of varieties that are now placed on the National List for winter and spring wheat. However, the number of varieties placed on the different lists for field crops do not show big differences through the years in the period 1959-2004. On average 14 varieties of winter wheat and six varieties of spring wheat were placed on these lists each year when measured each five years. Thereby, each variety was present on the list for a period of approximately 5-10 and replaced by other varieties.
In 2004 half of the cultivated varieties of winter wheat is placed on the Descriptive List of Field Crops (26 varieties) and thereby certified for marketing. For spring wheat 10 varieties are certified by placement on the Descriptive List of Field Crops. These 10 varieties comprise two third of the total number of varieties that are grown in the Netherlands in 2004. These numbers are without a minor number of old varieties of wheat that are maintained outside the agricultural market.

- Share of key crop varieties in marketed production

Share of different varieties of winter and spring wheat in 2004 is obtained from data on certification of areas for seed production. Thereby, the assumption is made that all produced seeds are sown, cultivated and harvested in the Netherlands. Following table gives the shares of the total area for different varieties of winter and spring wheat in 2004.

Table 8. Varieties registered for market production.

Winter wheat			Spring wheat		
variety	share (%)	placed on list	variety	share (%)	placed on list
Akteur	0		Alexandria	0	X
Alceste	0		Anemos	1	X
Alonso	1		Baldus	10	X
Alsace	0		Cadenza	0	X
Apache	0		Echo	0	X
Bercy	0	X	Lavett	11	X
Biscay	1		Melon	3	
Bristol	6	X	Minaret	10	X
Bussard	0		Monsun	1	
Canari	0	X	Pasteur	27	X
Cardos	0		Sunnan	0	X
Cebeco 01	0		Taifun	7	
Cebeco 02	0		Torka	1	
Chatelet	0		Tybalt	28	X
Claire	4		Zirrus	2	
Cubus	1				
Drifter	22	X			
Enorm	0				
Estica	0	X			
Exsept	0				
Farandole	0	X			
Florida	1				
Globus	2				
Harrier	0	X			
Harlem	0	X			
Hattrick	1				
Hedvika	0				
Hereward	0	X			
Ilias	11	X			
Kampa	2	X			
Koch	0	X			
Limes	5	X			
Napier	0	X			
Oriolus	0	X			
Parador	0				
Residence	20	X			
Riant	0	X			
Ritmo	0	X			
Robigus	0				
Skater	1				
Semper	1	X			
SW Tataros	15	X			
Tambor	0	X			
Tommie	0				
Tower	0	X			
Tremie	0				

Winter wheat			Spring wheat		
variety	share (%)	placed on list	variety	share (%)	placed on list
Tulsa	2	X			
Versailles	0	X			
Virtuose	1	X			
Vivant	1	X			
Winnitou	1				

Data from the Variety List of Field Crops and the Dutch Inspection Service (NAK).

From the table it follows that for winter wheat two varieties (Drifter and Residence) each occupy 20% of the total area. Besides these two varieties also SW Tataros and Ilias cover a considerable part (resp. 15% and 11%) of the area. For spring wheat Pasteur and Tybalt are the most important varieties. They each have a share of more than a quarter of the total area of spring wheat. Three other summer wheat varieties with considerable shares of the total area of spring wheat are Lavett (11%), Minaret (10%) and Baldus (10%).

Organic wheat cultivation in the Netherlands is not included in these figures. In the Netherlands the areal with organic wheat is approximately 2000 hectares. It is estimated that 60%-70% of this area consists of spring wheat (varieties Lavett, Melon and Pasteur). For winter wheat it is not know how large the area is.

- Number and share of national crop varieties that are endangered

For wheat there are only a few small organizations and individuals occupied with the conservation of old and endangered varieties. It is not known how many old varieties are currently maintained and in danger. Foundation 'De Oerakker' is an organization which tries to maintain old Dutch varieties of wheat (besides various other crops).

Extended set

- Average size of farms

In 2004 cereals were cultivated on more than 17,000 farms, with an average size of just more than 8 ha. Approximately half of these farms were 0.01-7 ha and half of these farms were 7 ha or larger.
Also, for 2004 it was estimated that in total 1248 million kg of wheat would be harvested from 139 thousand hectares. More specific numbers for winter and spring wheat are given in the table below.

Table 9. Production of wheat in the Netherlands in 2004.

2004	Harvested area (ha)	Harvest (1000 kg)	Harvest per ha (kg)
Winter wheat	118,366	1,090,300	9,200
Spring wheat	21,048	158,300	7,500
Total	139,414	1,248,600	9,000

Data from CBS, StatLine, www.cbs.nl.

- Number of domestic and non-domestic registered key crop varieties

As described before, 26 and 10 varieties of respectively winter and spring wheat are included in the National List of 2004. Of the varieties that are placed on the National List, for 15 (58%) varieties of winter wheat and for seven (70%) varieties of spring wheat the breeding rights are developed by Dutch breeding companies.

- Share of three major crop varieties in seed production area /diversity index

Since the share of each variety of winter and spring wheat is derived from figures on seed production, share of the three major crop varieties can be calculated by summing up the shares of the major varieties for winter and spring wheat. For winter wheat the total share of Drifter, Residence and SW Tataros in the total seed production is 57%. For spring wheat the total share of Tybalt, Pasteur and Lavett in the total seed production is 66%.

- Number of endangered crop varieties

At the moment there is no information on this indicator for wheat. A definition of 'endangered' has yet to be formulated and this would also require collecting more information on landraces. It may be the case that information on the ex situ conservation of wheat varieties gives more information on the status of endangerment, or could be used to formulate a definition of endangered comprising, say, landraces whose presence in production has dropped to a certain share (as a category distinct from landraces present only in ex situ collections).

- Number of varieties conserved ex situ

At the Plant Genetic Resources (PGR) cluster of the Centre for Genetic Resources, the Netherlands also wild, research, breeding material as well as varieties and land varieties of wheat is conserved ex situ.
In the genebank collection 4,582 accessions of *Triticum aestivum* are conserved from 87 different countries. Of these accessions, 1,482 accessions represent breeder's varieties, 2,299 accessions represent land varieties and 659 accessions represent research material. For the rest of the accessions, the population type is not coded. In the documentation system 1,347 distinct names for breeder's varieties and 1,097 distinct names for land varieties are included.

In the gene bank collection, 159 accessions are included with an origin from the Netherlands. Of these accessions 132 accessions are breeder's varieties, three accessions are land varieties (*Zeeuwse Witte*, *Limburgse Kleine Rode* and *Gelderse Ris*) and 24 accessions are typed as research material. In the following table the breeder's varieties and land varieties that originated from the Netherlands and are included in the gene bank are listed.

Table 10. Accessions of Triticum aestivum that are conserved in situ at the Dutch genebank. Origin country of the accessions is the Netherlands and accession are either breeder's varieties (plain text) or land varieties (text in italics).

Name	Number of accessions	Name	Number of accessions	Name	Number of accessions
Accent	1	Imperiaal I	1	Pagode	1
Addens	1	Imperiaal IA	1	Princ Heinrich	1
Adonis	1	Imperiaal II	1	Prins Hendrik	2
Algebra	2	Imperiaal IIA	1	Promessa	1
Amadant	1	Inflatum-1	1	Ricardo	1
Amethyst	1	Inflatum-2	1	Ritmo	1
Apollo	2	Jacob Cats	2	Robusta	1
Arminda	1	Jofe	1	Rode Dikkop	1
Arnaut	1	Jondolar	1	Rode Ris	1
Avir	1	Juliana	2	Rotonde	1
Baldus	1	Kaspar	2	Saiga	1
Bastion	1	Klaroen	2	Sambo	1
Batauwe	1	Kruisingsangel	1	Sarina	1
Bercy	1	Lancer	1	Sarno	1
Bonus	1	Lely	2	Sicco	1
Canari	1	*Limburgse Kleine Rode*	*1*	Solid	1
Clement	1	Limburgse Kleine Rode no1	1	Spelt v. Hooster	1
Cleo	2	Lovink	1	Staring	2
Concurrent	1	Löwing Tarwe Holender	1	Stratos	1
Demeter	2	Mado	2	Swifta	1
Diekhuis tarwe	2	Manella	2	Tavero	2
Donata	1	Mansholt's Japhet	1	Titan	1
Echo	1	Mansholt's Witte	1	Toro	1
Eiffel	1	Mansholts Witte Dikkop I	1	Tower	1
Elisabeth	2	Mansholts Witte Dikkop III	1	Tumult	1
Emma	2	Matador	1	Tundra	1
Estica	1	Melchior	2	Vada	1
Falco	2	Mildress	3	Van Hoek	1
Fitty	1	Miller	1	Versailles	1
Fletum	2	Millioen IV	1	Wageninger	1
Flevina	2	Minaret	1	Wilhelmina	2
Gelderse 42	1	Nautica	2	Willem I	1
Gelderse Ris	*1*	Nieuwe Angel	1	Wilobo	1
Gelderse Ris	1	Obelisk	1	Wodan	2
Groninger	1	Orca	2	*Zeeuwse Witte*	*1*
Hector	1	Oude Ris	1	?	1

- Intensification and use of modern breeding strategies

It is not known which modern breeding strategies are applied for the development of new varieties for spring and winter wheat. Probably, new techniques are applied in the programs of the breeding companies when new varieties are developed.

- Percentage of seeds originating from own farm

The figures on seed production and propagation from the Dutch Inspection Service (NAK) only show areas that are applied for certification. In these figures seed production and propagation on the own farm are not included. Also, the Dutch Inspection Service (NAK) does not have figures on seed production and propagation on the own farm. As a result, if available, data on this will be hard to collect.

- Share of crop varieties and species adapted to landscapes/production environments important for biodiversity and/or characteristic for a region or country

For wheat, land varieties have disappeared in the Netherlands. The only land varieties that are conserved in the Netherlands are included in the genebank or conserved by private organizations. Some varieties are included in small scale production that's characteristic for a particular region. Mr. R. Walrecht from organization 'De Nieuwe Akker' mentioned three old land varieties that are cultivated on a small scale in Groningen and Zeeland: Ommelander Ris, Gelders Ris Weit and Zeeuws Vlegel.

In the collection of 'De Nieuwe Akker' the following varieties are included:

Zeeuwse witte (winter wheat)
Gelderse risweit (winter wheat)
Ommelander risweit (winter wheat)
Kleefse risweit (winter wheat)
Limburgse kleine rode (winter wheat)
Elisabeth (winter wheat)
Rode dikkop (winter wheat)
Juliana (5 different types in collection)
Mayr (a few varieties)

- Area of low production/high biodiversity

There are no statistics available on the area of low production/high biodiversity of wheat. Areas that may be considered under this indicator are cultivations of biological wheat. Mr. A. Osman of the Louis Bolk Instituut estimates that the area of biological wheat in the Netherlands is approximately 2000 hectares. This would be about 1.4% of the total area cultivated with wheat. On average 60-70% of this area is spring wheat.
Winter wheat is especially cultivated at BV ERF in Zeewolde. Currently, they grow 347 ha of winter wheat which consist of the varieties Renan, Cardos, Tambor and Globus. Also, 100 ha of the intermediate variety Melon is cultivated (Roskam, pers. com.).

- Number of breeders per crop

For wheat this might turn out to be an important indicator. Where there used to be several Dutch breeding companies involved in the development of new varieties of wheat, in 2004 there are only two breeding companies active in this crop in the Netherlands: Cebeco BV and Wiersum BV, Landbouwbureau. Besides these two breeding companies some research institutes have been busy with pre-breeding or research on varieties for the biological agriculture. Also, some amateur-breeders may be active in wheat breeding.

- Number of different breeding goals

It is not known what the different breeding goals of breeding companies for the new development of varieties of spring and winter wheat are. In the Variety List of Field Crops characteristics are given that refer to winter hardiness, strength and length of straw, earliness, bread-making quality, suitability as a nurse crop and resistance to yellow rust, brown leaf rust, mildew, leafspot, *Fusarium* in the ear and black molds in the ear. Since these characteristics are important for a good crop, they are most probably included in breeding programs.

Restricted set

- Percentage seed originating on farm of three major (high production) breeds

The figures on seed production and propagation from the Dutch Inspection Service (NAK) only show areas that are applied for certification. In these figures seed production and propagation on the own farm are not included. Also, the Dutch Inspection Service (NAK) does not have figures on seed production and propagation on the own farm. As a result, if available, data on this will be hard to collect.

- Number of characteristic varieties stored in gene bank

In the gene bank three different landraces of *Triticum aestivum* are conserved (i.e. *Zeeuwse Witte*, *Gelderse Ris* and *Limburge Kleine Rode*). Of the varieties that are included in the genebank six accessions of six varieties of winter wheat (Bercy, Canari, Estica, Ritmo, Tower and Versailles) and three accessions of three varieties of spring wheat (Minaret, Echo and Baldus) were cultivated (according to data on seed production) in the Netherlands in 2004.

Latent diversity

An increase in the number of different varieties on the Variety List of Field Crops does not directly represent an increase in agrobiodiversity. Not all varieties on this list are cultivated in the Netherlands and also differ in their shares in the total area of cultivated winter and spring wheat. Also, besides the varieties on the list, other varieties are cultivated in the Netherlands. Information on the cultivated areas from the Dutch Inspection Service (NAK) as well as information on additional cultivated varieties (whereby 'old' varieties and biological wheat are included) enables an estimation of the relative importance of each variety in the total cultivation of wheat in the Netherlands.

However, even if the relative importance of each variety can be determined and compared over the years, an increase in the number of varieties that make up the main part of wheat cultivation in the Netherlands does not necessarily mean that agrobiodiversity is gained. For a more sound estimation of loss or gain of agrobiodiversity the genetic diversity between the varieties has to be determined. For the 26 varieties of winter wheat in the Variety List of Field Crops of 2004 the varieties Ilias and Kampa and the varieties Farandole and Virtuose have been derived from crosses with (almost) the same varieties as genetic resources. Also, the list shows that almost all varieties are derived from crosses between other varieties. As genetic resources for the 26 varieties of winter wheat and 10 varieties of spring wheat on the list, respectively 42 and 19 varieties and lines are mentioned as genetic resources.

Genetic relationships between Dutch wheat varieties in 1960 are represented above. The scheme is included in Zeven, A.C. (1990; pp. 90-2). One variety, Wilhelmina, dominates the picture as all later varieties are descendents of this variety.

Because of redundancy and the in majority use of the same varieties as genetic resources for the production of new varieties it can be expected that the genetic differentiation between the current cultivated varieties is not very large. Genetic studies of varieties of wheat may support this idea.

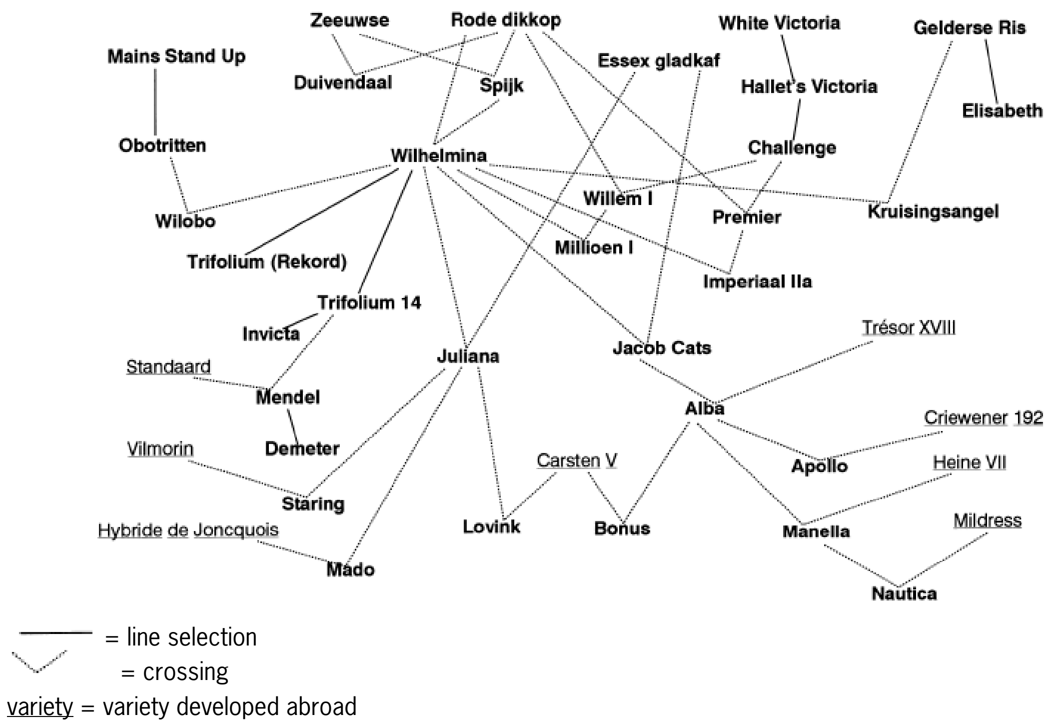
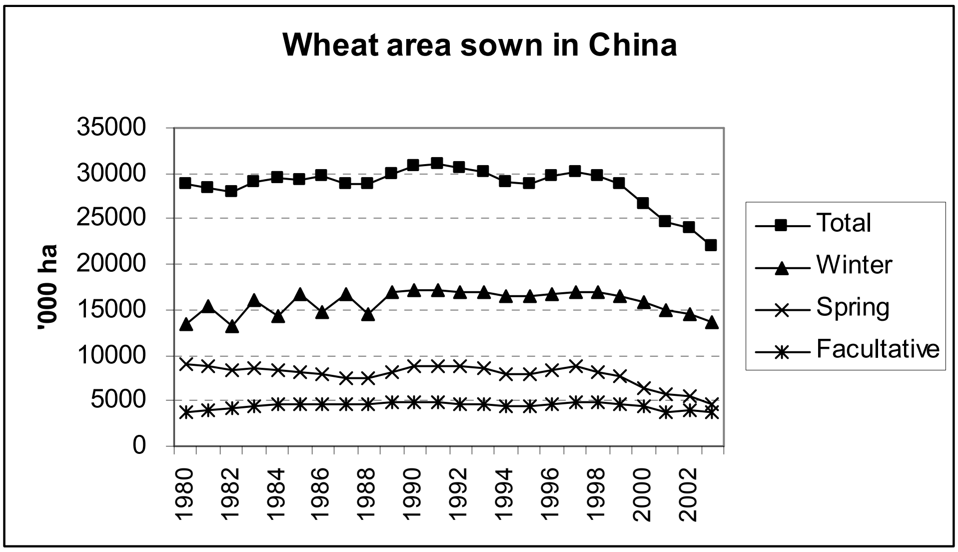


Figure 5. Pedigree relationships of Dutch wheat varieties in 1960 (after Zeven 1990).

4.2.2 Wheat diversity in China

Wheat is one of the big three grain crops of China, together with rice and maize, and China is the largest producer of wheat in the world. China has a history of more than 5000 years of wheat cultivation. Area sown to wheat was estimated at almost 22 million ha in 2003. Both production and sown area have, however, fluctuated dramatically in the recent decade. From 1980 up until 1997, wheat production more than doubled to over 120 million tonnes, largely due to increasing yields per hectare. During peak years in the 1990s, more than 30 million ha was sown to wheat. Since 1997, many farmers have switched land out of wheat production (particularly of low quality by high-yielding types of wheat), opting for more profitable options such as horticultural crops (see Lohmar, 2004). This has particularly been seen in northern areas growing spring wheat, where grain quality has remained poorer. Yields have thus not dropped as much as sown area in relative terms, as can be seen in the figures.



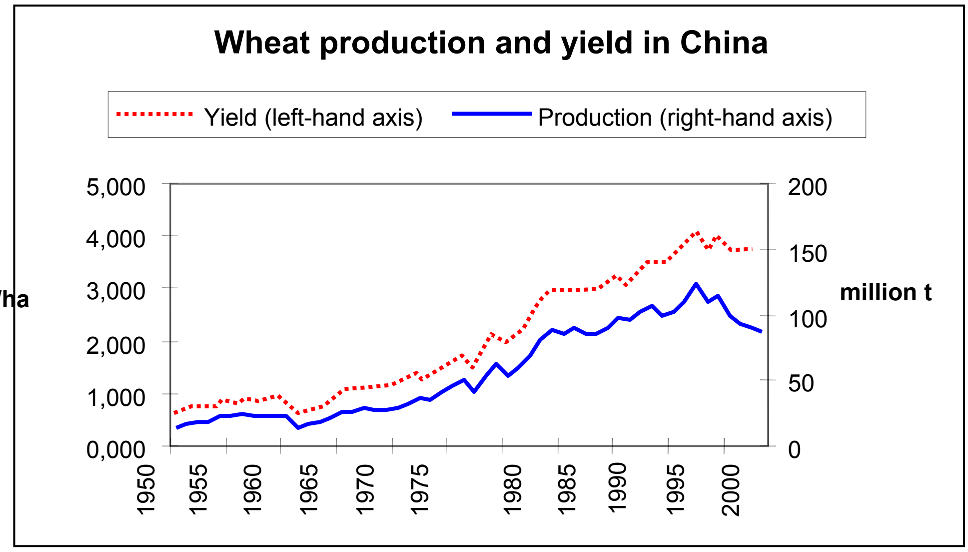


Figure 6. Wheat area (top) and total production (bottom) in China.

Wheat is planted in both autumn and the spring. Varieties in China are classified according to the sowing period: winter, spring and facultative (for the most part, spring wheats that are sown in autumn). Winter wheat now accounts for about 85% of sown area. Area sown to spring wheat

The history of wheat breeding and improved varietal adoption in China has been classified into four waves corresponding to varietal replacement (see He *et al.*, 2001 for a detailed discussion from which this summary is drawn). Modern wheat breeding began in earnest after independence in 1949 and the early 1950s saw the evaluation and improvement of a number of landraces, as well as the introduction of foreign varieties in these breeding programmes. The second wave of varietal replacement began in the mid-1950s and included both further improvements of landrace-derived varieties as well as direct introduction of varieties, particularly from the U.S. and Italy. In the early 1960s, a yellow rust epidemic led to the third wave of varietal replacement with new rust-resistant varieties being released that were also early-maturing and having lower plant height and higher yield. Again this also include the direct introduction of foreign varieties, such as Abbondanza from Italy. A further wave of new varieties was released beginning in the early 1970s with improved rust resistance and yield potential. In the early 1980s a fifth wave of varietal replacement began with new improved varieties derived from crosses with 1BL/1RS derivatives conferring improved rust and powdery mildew resistance. The sixth wave, beginning in the 1990s, contained yet further improvements to such resistance.

Under the 'Seed Law of the People's Republic of China', passed in 2000, new varieties of major crops, including wheat, must pass 2-3 years of agronomic trials and be approved at the national or provincial level before being marketed and cultivated. Until 1996, approved varieties were required to demonstrate a yield gain of at least 5%. Since then, a relaxation of this requirement has resulted in an increase in the number of varieties approved for cultivation. Prior to this change, provinces typically approved one or two new varieties per year, but since then this has increased to approximately three to six.

CBD indicator

- Total number and share of main crop varieties

The total number of wheat varieties is presented in the following table for the years 1982, 1992 and 2002 (data for 2004 is not yet complete). These are varieties that are cultivated. These varieties account, in effect, for 100% of the area sown to wheat. The area shares of the most common varieties is presented further below.

The number of varieties has increased from 1982 to 1992 and again to 2002. But the number of facultative varieties has decreased somewhat during the period from 1992 to 2002, compensated by a greater growth in the number of winter wheat varieties, representing primarily a shift in cropping patterns as mentioned above.

Data on all of the varieties cultivated, including the area sown to each variety, has been collected by researchers for years beginning in 1982. Area shares are presented further below for the most widely cultivated varieties. A problem with this indicator is the criteria to be used for determining which are the main crop varieties. This is further seen below with respect to the OECD indicator for share of key crop varieties in marketed production.

Table 11. Total number of crop varieties.

	1982	1992	2002
	# varieties	# varieties	# varieties
Winter wheat	47	76	215
Facultative	53	75	55
Spring wheat	62	88	125
Total	162	239	395

Data from the Center for Chinese Agricultural Policy, Chinese Academy of Sciences.

OECD indicators

- Number of registered and/or certified crop varieties for marketing

The following table presents numbers of the varieties that have been cultivated (see above) and that are registered and on national or provincial varietal lists. This information was not readily available for 2004, but could be obtained with further research. Almost all of the varieties cultivated in 1982 and 1992 were registered. Only one facultative variety and one spring wheat variety cultivated in 1992 were not on the list. This list however needs to be expanded with varieties that were on the list but not cultivated. This would presumably show an even greater increase over the years. It is not clear if varieties are ever removed from the list, or if it can only grow larger.

Table 12. Number of varieties certified for marketing.

	1982	1992	2004
	# varieties	# varieties	# varieties
Winter wheat	47	76	n.a.
Facultative	53	74	n.a.
Spring wheat	62	87	n.a.
Total	162	237	n.a.

- Share of key crop varieties in marketed production

The table below lists the top ten varieties per wheat type and their share of area cultivated for each of the three years studied. There is no standard definition of what constitutes key varieties. One possibility is to use a cut off value for the share of cultivated area. In this study an arbitrary choice was made to include the ten most cultivated varieties (by area) which does not seem to be such a high number given the extent of wheat cultivation in China and the diversity of growing conditions.

Table 13. Ten most widely-cultivated varieties and area shares.

Winter wheat					
1982		1992		2004	
variety	share (%)	variety	share (%)	variety	share (%)
Chang Le5 Hao	13.1	Lu215953	10.8	ZhengMai 9023	9.4
Aifeng 3 Hao	9.3	XiaoYan6 Hao	8.2	YanNong19 Hao	5.8
Bei Jing10 Hao	6.6	Jin Mai 33 Hao	8.0	JiMai 19 Hao	5.6
XiaoYan6 Hao	6.5	LuMai 13 Hao	6.5	YuMai 34	3.5
Dong Fang Hong 3 Hao	6.0	TangShan6898	5.9	Han6172	3.3
JiMai 1 Hao	5.7	LuMai 12 Hao	4.6	WanMai 19	3.0
Bei Jing10 Hao	5.2	Jin Mai 16 Hao	3.5	YuMai 70	2.5
JiMai 3 Hao	4.4	Chang Wu131	3.0	JiMai 20 Hao	2.4
KeYiMai	4.4	YuanDong3 Hao	2.9	ChuanMai 107	2.1
JiMai 7 Hao	4.1	FengKang8 Hao	2.6	Yu Mai 49	2.0
Total	65.2	Total	56.1	Total	39.6

Facultative wheat					
1982		1992		2004	
variety	share (%)	variety	share (%)	variety	share (%)
TaiShan1 Hao	24.3	LuMai 14 Hao	9.7	YuMai 18	80.7
Ji Nan13 Hao	8.9	YuMai 13 Hao	7.4	YanNong15 Hao	6.1
Feng Chan3 Hao	8.7	JiMai 30 Hao	6.6	EEn1 Hao	4.0
ShanNongFu63	7.5	XiAn8 Hao	6.3	YuMai 2 Hao	2.9
Bai Nong3218	6.0	LuMai 15 Hao	6.2	LuMai 1 Hao	2.7
TaiShan5 Ha	5.0	EEn1 Hao	5.7	MianYang20	1.0
EMai 6 Hao	4.1	JiMai 26 Hao	4.2	YuMai 19	0.7
ZhengZhou761	3.9	LuMai 1 Hao	3.9	Jin Mai 31	0.7
Bo Ai7422	3.4	YuMai 18 Hao	3.9	XinLuoBa Hao	0.7
Abbondanza	2.9	MianYang20 Hao	3.5	LuMai 15 Hao	0.5
Total	74.6	Total	57.4	Total	99.9

Spring wheat					
1982		1992		2004	
variety	share (%)	variety	share (%)	variety	share (%)
Bo Ai7023	17.2	YangMai 5 Hao	17.8	YangMai 158	19.1
Fan6	8.6	XinKeHan9 Hao	9.9	NingChun4 Hao	15.8
MianYang11 Hao	8.4	YuMai 17 Hao	6.9	LongMai 26	13.4
YangMai 3 Hao	8.1	MianYang19 Hao	6.1	MianYang19	4.3
St 1472/506	6.9	MianYang15 Hao	5.4	XinChun6 Hao	3.8
KeHan6 Hao	4.5	808	5.2	LongMai 29	2.9
Funo	4.5	Wan7107	4.4	Hong MangMai	2.6
KeFeng2 Hao	4.0	KeHan10 Hao	3.1	KeFeng10	2.2
NingMai 3 Hao	3.0	MianYang21 Hao	2.7	NingChuan16	2.1
Wan7107	2.9	ChuanMai 22 Hao	2.0	Abbondanza	2.0
Total	68.2	Total	63.7	Total	68.1

- Number and share of national crop varieties that are endangered

There is currently no list of endangered varieties in China. Criteria for such a list would have to be defined and the list would have to be compiled by wheat specialists. As noted, wheat experts are quite sure that traditional landraces are not cultivated anymore in China. Other varieties might be endangered with disappearance from production systems as well. Criteria need to be defined though for the extent of in situ and/or ex situ conservation that would determine a cut-off point for endangered status.

Extended set

- Average size of farms

The following table shows the average size of farms cultivating wheat. From 1982 to 1992, farm size decreased on average and then, by 2002, increased again. For Spring wheat, this increase in farm size is more marked than for winter or facultative wheat-growing farms. This is probably related to the shift in wheat cropping patterns noted above, as proportionally more land has moved out of spring wheat production than out of winter wheat production, which occupies much more land in the first instance.

If one assumes that larger average size of farms implies fewer varieties being cultivated, then this indicator is difficult to interpret. This assumption would suggest that the diversity of varieties might have increased from 1982 to 1992 and then decreased from 1992 to 2002. This is somewhat corroborated by the area shares for the top three and top ten most widely-cultivated varieties presented respectively below and above. Nonetheless, there may be other explanations for the trends in average farm size that are to be found in other general trends in Chinese agriculture and land tenure systems.

A smaller average size of wheat farms may also indicate a greater presence of very small, less-commercialized farms that still undertake on-farm varietal selection and even improvement. However, in this case Chinese wheat experts maintain that such practices have all but vanished in the case of wheat varieties and thus the indicator should not be interpreted in such a manner.

Table 14. Average size (ha) of wheat farms.

	1982	1992	2002
Winter wheat	0.55	0.42	0.43
Facultative	0.41	0.32	0.35
Spring (North)	1.41	1.23	1.60
Spring (South)	0.34	0.27	0.34
National Average	0.54	0.42	0.55

- Number of domestic and non-domestic registered key crop varieties

The varieties cultivated and listed above have been classified according to whether they are Chinese varieties or foreign varieties introduced in China. The totals of domestic and foreign varieties by wheat type are presented in the following table for each of the three years. Over the period spanned, the share of foreign varieties has decreased. It is important to note though that the category for domestic also includes improved varieties of combined foreign and Chinese pedigree. Introduction of foreign varieties into Chinese breeding programmes began in the 1950s. So this indicator captures only the integral presence of foreign varieties in Chinese wheat production, not the presence genetic resources of foreign origin.

Table 15. Number of varieties by origin.

	1982		1992		2004	
	Domestic	Foreign	Domestic	Foreign	Domestic	Foreign
Winter wheat	46	1	76	0	n.a.	n.a.
Facultative	51	2	74	1	n.a.	n.a.
Spring wheat	53	9	84	4	n.a.	n.a.
Total	162	12	234	5	n.a.	n.a.

- Share of three major crop varieties in seed production area /diversity index

The share of the three major crop varieties is calculated and presented in the following table together with the Shannon diversity indices for the varieties cultivated in the three years. The area accounted for by the top three varieties declined for winter wheat while the Shannon index increased. This contrasts with both the facultative and spring wheats where there was first an increase in the diversity index (and decline in the area of the top three facultative varieties) in 1992 relative to 1982, but followed then by a sharper decrease in the diversity index in 2004. For facultative wheats the area accounted for by the top three increased dramatically to 90 %, of which 80% is accounted for by the leading variety, YuMai 18. These changes over time are also reflecting to some extent changes in cropping patterns and the growth in winter wheat area, at the expense of both facultative and spring wheats.

Table 16. Share of three major crop varieties and Shannon diversity index.

	1982		1992		2004	
	Area share top 3 (%)	Shannon Index	Area share top 3 (%)	Shannon index	Area share top 3 (%)	Shannon index
Winter wheat	29.0	3.30	27.0	3.65	20.8	4.47
Facultative	41.9	2.96	23.7	3.53	90.8	0.85
Spring wheat	34.2	3.20	34.6	3.42	48.3	3.04

- Number of varieties conserved ex situ

Of the varieties that are being cultivated, all are conserved ex situ in genebanks, reflecting the fact that these are almost entirely improved varieties (i.e. not landraces). Thus, the following table is not very informative given the predominance of improved varieties.

Table 17. Number of marketed varieties conserved ex situ (minimum).

	1982	1992	2002
	# varieties	# varieties	# varieties
Winter wheat	47	76	215
Facultative	53	75	55
Spring wheat	62	88	125
Total	162	239	395

Many other varieties are also conserved in genebanks. The national crop genebank, located at the Crop Germplasm Institute of the Chinese Academy of Agricultural Sciences, is the most important one in China with the largest and most diverse collection. The following table shows that more than 37,000 accessions were stored in the genebank as of 1996. Information is not readily available from the genebanks as to how many varieties are represented in the collection.

Table 18. Number of wheat accessions documented and stored at Chinese national crop genebank.

Types of varieties	Lines documented (number)	Lines stored (number)
Chinese	23,500	23,000
Foreign	13,500	12,000
Rare	2,100	1,400
Wild	2,200	700
Genetic stocks	900	600

Reproduced from He et al. (2001), p. 13; original source: Chinese Academy of Agricultural Sciences

- Intensification and use of modern breeding strategies

As indicated in the following table, essentially all wheat varieties cultivated are improved varieties derived from modern breeding strategies. According to He *et al.* (2001), hybridization is still the most popular method used for wheat breeding in China, supplemented by induced mutation, anther culture and wide crosses. In the last decade, considerable interest and investment has also gone to the development of hybrid wheat varieties and the use of modern biotechnology in breeding, including research on transgenic wheat varieties (though none have yet been commercialised).

The extent to which modern breeding strategies are used does not however capture how much genetic diversity is being used. Thus, although all varieties are produced by breeding programmes, primarily in public research institute, using modern breeding strategies, most of these programmes are based on incorporating resistance or tolerance for abiotic stresses from Chinese landraces. Foreign varieties are used, on the other hand, primarily for short plant height, higher yield and stronger disease resistance. He *et al.* (2001) report that more than half of the varieties developed during the period 1950-86 involved crosses between imported varieties and Chinese landraces or their derivatives. This does mean though that selection and improvement by farmers in the context of local environments is essentially not happening at all anymore in China and this is what this indicator does capture.

Table 19. Share of modern varieties (percent number and area).

	1982		1992		2004	
	# varieties	Area	# varieties	area	# varieties	area
Winter wheat	97.9%	99.1%	100%	100%	100%	100%
Facultative	100%	100%	100%	100%	100%	100%
Spring wheat	95.2%	95.4%	100%	100%	100%	100%
Total	97.5%	98.2%	100%	100%	100%	100%

Varieties are classified as either modern or traditional

- Percentage of seeds originating from own farm

There are no official statistics in China on the percentage of seed sown, including for wheat, that farmers have saved from the following season for planting. Agricultural economists of the Center for Chinese Agricultural Policy (CCAP) of the Chinese Academy of Sciences estimate, based on their regular surveys and research in wheat producing areas, that the average percentage of wheat seed saved has declined from approximately 50% in 1982, to 40% in 1992, and to 30% in 2004 (see Table). This seems to indicate that farmers perceive greater benefits from purchasing new seed each year. It is important to note that all of the seed saved concerns improved varieties as there is practically no evidence of wheat landraces still being cultivated in China, as discussed in relation to the next indicator.

Table 20. Estimated percentage of wheat seed sown from farm-saved seed.

	1982	1992	2002
%sown on farm	50%	40%	30%

- Share of crop varieties and species adapted to landscapes/production environments important for biodiversity and/or characteristic for a region or country.

Within the limitations of the study, it was not possible to determine which of the varieties cultivated could still be termed 'characteristic' (for which a criterion needs to be elaborated). Given the available information though on the development of Chinese wheat breeding programmes, and other sources (e.g. He *et al.*, 2001; Tian *et al.*, 2005), it seems unlikely that any characteristic varieties of wheat still in cultivation would account for more than a very small share of cultivated area (<1%). This has been verified with wheat experts at the Chinese Academy of Sciences.

- Area of low production/high biodiversity

This indicator has not been estimated given the lack of available information, and to some extent a lack of indication as to how this indicator should specifically be defined. As already indicated, almost all wheat production in China apparently takes place with improved varieties. This study has not found easily accessible evidence of low production, highly diverse wheat-based cropping systems in China where farmers continue to select their own local varieties. But some wheat farming undoubtedly occurs in lower production environments with higher levels of biodiversity, and this may involve some local experimentation and adaptation with improved varieties, which would be interesting to monitor from a biodiversity perspective. But this implies setting a strict definition for the indicator (which would probably have to be specific to different crops and to the country in question) as well as devoting resources to identifying, through expert opinion and surveys, where such production takes place.

- Number of breeders per crop

The general overview of wheat breeding in China undertaken by He *et al.* (2001) lists 38 major breeding institutes present in China in 2000, but this list also does not include a range of smaller, more local organizations undertaking wheat breeding. Nor does the list include private sector companies that are undertaking breeding activities. The Center for Chinese Agricultural Policy of the Chinese Academy of Sciences estimates that there in total approximately 300 organizations conducting wheat breeding research in China at the moment. A more accurate inventory would have to be undertaken by means of a survey. In such a manner, it might also be possible to collect information on how many breeders are employed by these organizations.

- Number of different breeding goals

Assessing the number of different breeding goals is hampered by the lack of a consistent definition or classification of breeding goals at different levels. For example, higher yield potential as a breeding goal can be achieved by a number of breeding 'sub-goals', such as for example increasing kernel weight per spike, or broad adaptation. From the point of view of using genetic diversity, counting such sub-goals, or second-order goals, might be more useful and informative.

Assessing the number of different breeding goals systematically would also involve some kind of survey among wheat breeding organizations, which is currently not available. On a more qualitative note, the discussion above has highlighted how breeding goals in the 1960s first expanded to include rust resistance and that this further broadened in the 1970s and 1980s to include a wider range of biotic stresses, such as powdery mildew. According to He *et al.* (2001), current breeding goals include at least five general goals: high yield potential (long spike materials with more kernels or higher kernel weight per spike, semi dwarf stature), broad adaptation, good stability, resistance to biotic and abiotic stress (especially drought tolerance), and industrial quality (suitability for bread-making and noodle-making). Thus, in general, the number of wheat breeding goals has expanded over the past five decades. Some of these goals suggest a more intensive use of Chinese genetic material (landraces and derivatives) while others involve continued intensive use of foreign material.

Restricted set

- Percentage seed originating on farm of three major (high production) breeds

The estimates of percentage seed originating on-farm (farm-saved seed) provided above in the extended set can not be further specified for the major, or most widely cultivated, varieties. Thus, the estimates of 50% in 1982, 40% in 1992 and 30% in 2004 provide the best available proxies, and precise estimates would have to be obtained from farm surveys. There is some reason to expect that the percentage originating on-farm will be lower for the three major varieties (most widely cultivated) than for the overall average, at least among the most efficient and highly commercialized farmers.

- Number of characteristic varieties stored in gene bank

As seen above, the number of varieties stored in the national wheat genebank as of 1996, included 1,400 that were classified as 'rare' and 23,000 that were classified as 'Chinese'. Neither of these categories corresponds to 'characteristic'. It seems plausible that a number of rare varieties might be characteristic for certain regions of the country, and that also some of the many 'Chinese' landraces might also meet this criterion. This information could only be compiled in a country such as China by consulting with a number of wheat experts to identify which varieties should be termed characteristic, which would also include agreeing upon a definition.

Latent diversity

A recent study (Tian *et al.*, 2005) has characterized 242 accessions of wheat released in China since the 1940s using the AFLP (amplified fragment length polymorphism) technique. The varieties were characterised according to their decade of release and for each group, a diversity index was calculated as the average Simpson index of primers. The numbers of varieties per decade and the genetic diversity index are reproduced in the following table.

Table 21. Number of varieties and genetic diversity index based on AFLP polymorphism per decade (after Tian et al., 2005).

Release decade	Number of varieties	Genetic diversity index
1940s	54	0.1343
1950s	15	0.1353
1960s	22	0.1302
1970s	44	0.1286
1980s	58	0.1329
1990s	49	0.1294

Data reproduced from Tian et al. (2005).

Latent diversity according to this measure was highest in the group of varieties released in the 1950s, even though this was by far the smallest group of varieties among those studied. This represents the introduction of foreign varieties from the U.S. and Italy into Chinese wheat breeding programmes during the 1950s. In general, there is an overall trend of decreasing diversity although the index was lowest among the varieties from the 1970s and then jumped considerably for the group in the 1980s.

It is unfortunately not clear what the basis for selecting the varieties was in the study. They are all held in the national genebank collection in Beijing and presumably represent a selection of the most important (i.e. cultivated) varieties and cover a broad range of diversity. Almost all of the 54 varieties from the 1940s group were landraces, whereas most of those from the 1950s group were either improved varieties or foreign introductions. For the 1960s, 1970s and 1980s, almost all of the varieties studied were improved varieties from Chinese breeding programmes, although foreign varieties probably form part of the varieties pedigree (given information provided by He *et al.*, 2001)

The latent diversity does not distinguish between sources of diversity. Thus genetic diversity introduced from foreign varieties is given equal weight to similar 'amount' of diversity from domestic landraces. Presumably a similar study could be repeated in which this contribution is differentiated, if the focus of interest is on trends in the diversity of genes of domestic origin, at least in the recent past (see also Eding *et al.*, 2006).

Aside from this AFLP study, data is also available (at the Centre for Chinese Agricultural Policy, Chinese Academy of Sciences) on the pedigree of improved varieties adopted during the period 1982-2004. For about half of these varieties, pedigree data is available going back to landraces while for the other half, parentage is known for approximately three generations is available. With a detailed study, this could be further analysed and the data holes possibly filled in. It would then be possible to calculate coefficient of parentage (COP) indicators. Alternatively the methods of Eding (2002) can be used to calculate COPs from molecular data. The advantage of a molecular study is that the contribution of the 'founding' landraces to the current varieties can be assessed. (see discussion on latent diversity in section 3).

4.3 Conclusions from case studies

Table 22. Summary of indicators from case studies.

Livestock: chicken	NL	Vietnam	Crops: wheat	NL	China
Number of breeds	169	31	Number of varieties	66	395
Number of certified breeds	24	9	Number of certified varieties	36	395
Average size of farms			Average size of farms		
- area in ha		0.14	- area in ha	8	0.55
- number of animals	28000	57	- t crop produced	73	2.2
- animals / ha			- t / ha	9	3.9
Number of key livestock breeds			No. of registered key crop varieties		
- native endangered	17	9	- domestic	22	?
- native not endang.	3	6	- non-domestic	14	?
- non-native	4	16			
Share of the three major livestock breeds	99.9%	85%	Share of the three major crop varieties in production area	57% 66%	21% 91% 48%
- native	0.01%	85%			
Population size native breeds	50 - 1100	20 – 125 million	No. of endangered crop varieties	?	?
No. of breeds conserved *ex situ*	11	5	No. of varieties conserved *ex situ*	at least 1444	?
No. of accessions characterised	3000	0	No. of accessions characterised	4,528	37,700
Intensification and use of modern breeding strategies	Yes	Yes			
Application of high-selective breeding methods (such as embryo transfer)	Yes	Yes	Percentage of seeds originating from own farm	?	30%
Number of breeding males of breeds characteristic for landscapes/production environments important for biodiversity and /or characteristic for a region or country	150	25 million	Share of crop varieties and species adapted to landscapes/production environments important for biodiversity and /or characteristic for a region or country	<0.1%	<1%
			area of low production/high biodiversity	1.4%	?
No. of breeders associations per breed	2 - 100	1 – 12 million	No. of breeders / crop	2	300
No. of different breeding goals	3	7	No. of different breeding goals	5-6?	5-6?

Table 22 summarizes the results from the case studies. The overall conclusion is that diversity in the Vietnamese chicken is much larger than in Dutch chicken, mainly due to the enormous amount of low input scavenging chicken across the whole country. The high input breeds are to a large extent the same in both countries, and are almost the only chicken (99.95%) present in the Netherlands, while in Vietnam they reach at most 20%. The only area in which the diversity is better kept in the Netherlands is under cryo-conservation, which is not yet developed in Vietnam.

The picture is less clear for wheat. Presumably both in the Netherlands and China the original landraces have almost disappeared. Ex situ landraces have been preserved in gene banks, although it is not clear what fraction of landraces. These landraces have contributed to current varieties, but to what extent is not clear either. For both chicken and wheat the actual state of genetic diversity within high production breeds/varieties is unknown. It is remarkable that the high production breeds in chicken are to a large extent the same in Vietnam and the Netherlands. Probably this is also true to some extent for wheat, as both Dutch and Chinese current varieties are partly derived from crosses with American and other foreign varieties. Based on latent diversity it seems that diversity among Chinese wheat varieties has decreased over the last 20 years. However, there is no indicator studied in which this decrease is reflected. The number of varieties has increased and the Shannon diversity index, for example, shows an increase. This highlights the limitations of indicators based on numbers (and even shares) of varieties. Assessing trends in diversity in high production breeds and crops has proved difficult, and possibly only molecular studies can provide the answers.

Some of the indicators even seem to present an incorrect assessment of the situation. In particular, the number of livestock breeds (CBD indicator) gives the false impression that diversity is much larger in the Netherlands than in Vietnam. For wheat the number of varieties (CBD indicator) indicates that diversity is larger in China than in the Netherlands. This is what one might expect, given that China is a much larger country, but interest lies more in the relative amount of diversity conserved. In this regard, the number of wheat varieties in China has increased over time, whereas studies of latent diversity indicate that the diversity among these varieties has probably declined.

As might be expected, some indicators seem better suited for industrialized, as opposed to developing, countries, or economies in transition. For example, the number of registered or certified breeds does not take into account that local breeds are generally not registered in developing countries. This is demonstrated by the recent discovery of a previously unidentified local chicken breed in Vietnam. The indicator on the share of the top three breeds, has the implicit assumption that these breeds are relatively uniform high-input breeds, with a higher share corresponding to lower diversity. That this might not be appropriate in a developing country is seen in the Vietnamese case study where the dominant breed is the local, scavenging, low- input, household chicken (Ri breed). It's high share in the total population is here a reflection of its large diversity.

For wheat, information on local varieties or landraces was much harder to find than for chicken. This indicates that this indicator can only really be assessed if there are crop experts active in field work who would have personal knowledge of remaining areas of cultivation of landraces. In general, it appears that wheat landraces are no longer cultivated in either the Netherlands or China. In addition, information on the percentage of seeds is generally not to be found in official statistics, neither in China nor in the Netherlands. Probably the only way to gather this information would be an extensive survey of farms, which is a costly exercise, and may still be imprecise. Thus, measurability difficulties make an assessment of the soundness and relevance of such an indicator difficult to assess. For the ex situ conservation indicators in crops the number of accessions characterised is easily found, but not the number of varieties.

The number of breeders per crop or breed was relatively easy to determine (although not with much precision in China). The predominance of the Ri breed in Vietnam and the designation of all households maintaining these chickens as breeders means that this indicator provides a useful contrast. But a better assessment of the relevance of this indicator would require an assessment of its development over time. When individual farmers and households more or less stop with on-farm breeding activities, then the relevance of this indicator probably diminishes considerably. In particular, it is not clear that an increase in commercial breeders would represent an increased use of genetic diversity, as might be inferred from the situation in wheat breeding in China. Wheat breeding, particularly in public research institutes, has increased over the last 40-50 years, resulting in the development of more varieties, while landraces have pretty much disappeared from cultivation and latent diversity seems to have decreased.

The case studies indicate that a consensus definition of 'key' or 'main' varieties/breeds needs to be formulated; and this needs to take account of circumstances of production in country concerned. Key can either mean important with respect to population size and share (e.g. high production varieties of wheat or chicken in the Netherlands) or important in terms of biodiversity. Furthermore, the study showed that the foreign-domestic distinction was too crude, at least for wheat where breeding programmes typically involve crossing of varieties from various sources. A high-input breed dominating the world market may be of domestic origin (e.g. in the Netherlands Holstein-Friesians for dairy cows or Texel for sheep). A category more relevant for biodiversity seems to be local indigenous, low input breeds or varieties.

The advantage of focusing on low input indigenous breeds is that it covers at the same time part of the wild biodiversity. A disadvantage is that diversity in high production breeds is not taken into account. In varieties and breeds in which landraces have (virtually) disappeared, such as wheat in China and the Netherlands and chicken in the Netherlands, indicators based on low input breeds only show that diversity has almost disappeared. This may mean that such an indicator is only relevant at quite early stages of agricultural commercialisation. However, such an indicator may also capture efforts made to restore indigenous breeds and varieties. One recommendation that can be made based on the case studies for wheat, is that efforts should be made for in situ conservation of landraces since these are currently lacking.

The case studies have given little explicit attention to the appropriate timeframe for periodic assessments and comparisons of the indicators. As mentioned in earlier sections, the values of the various indicators are only relevant in terms of comparison to earlier values, including in particular the definition of a baseline. In focusing the attention within agricultural livestock breeds and crop varieties to landraces and/or low input breeds, one implicitly uses a timeframe. Diversity before 1950 was largely made up of these breeds and varieties. In the Netherlands these breeds and varieties have almost disappeared reflecting the loss of diversity in this period. However, a change in diversity in the current high production breeds cannot be captured by indicators based on local breeds or landraces, and probably has to rely on indicators of latent diversity.

5. Evaluation of indicators

The preceding section has attempted to apply the principal indicators that have been proposed for agricultural genetic resources. These indicators were measured, as much as possible in the context of a small study, for chicken genetic diversity in the Netherlands and Vietnam, and for wheat genetic diversity in the Netherlands and China. In this chapter, we analyse these various indicators in terms of their potential usefulness for policy formulation, implementation and monitoring. This analysis consists of a general assessment based on established criteria for indicators of agri-biodiversity, with the findings of the case study serving as illustrative examples.

Criteria for assessing indicator development
The OECD Joint Working Party on Agriculture and Environment (OECD, 2003), has identified four main criteria for assessing indicators, including agri-biodiversity:
- *policy relevance*: deal with issues important across states or relevant to CBD and other agreements
- *analytical soundness*: well founded based on international consensus, scientifically valid and comparable across states
- *measurability*: data available now or in the near future
- *interpretation*: clearly understandable by policy decision makers, stakeholders and the general public

The Subsidiary Body on Scientific, Technical and Technological Advice (SBSTTA) of the CBD has identified a longer list of criteria, including seven used for assessing individual indicators and an additional three for assessing sets of indicators (CBD, 2003b). But it is recognized that these criteria do not apply equally to all indicators. Rather a range of criteria assists in weighing up the specific potential and contribution of each indicator and these then need to be weighed against each other.

The criteria proposed for sets of indicators[9] are
- *representative*: the set provides a representative picture of the pressures, biodiversity state, responses, uses and capacity (coverage)
- *small number*: a smaller set is easier to communicate and less costly to measure
- *aggregation and flexibility*: sets should facilitate aggregation at a range of scales such as ecosystem types, national and international levels, and make use of consistent baselines.

In this study, the various sets of indicators are first assessed with respect to the relatively small number of criteria proposed by the OECD. The CBD criteria for sets of indicators can also be interpreted as being covered by the four OECD criteria, as follows. Representativeness is an aspect of the policy relevance. The desirability of limiting a set to a small number of indicators is reflected primarily in the criteria of interpretation as well as measurability, as far as costs are concerned. Finally, aggregation and flexibility is reflected as an aspect of analytical soundness. A more thorough assessment of the proposed sets of indicators would distinguish between criteria applied to single indicators and those applied to different (potentially overlapping) sets.

The various sets of indicators from the previous section (see Table 2) are discussed here, including
- the CBD set
- the OECD (2001) set
- Wetterich's (2003) set
- the proposed Extended list; and
- the proposed Restricted list

Relative scores for these sets of indicators are suggested in Table 3 for the four criteria proposed by the OECD Joint Working Party (OECD, 2003) and explained below taking each criteria in succession.

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9 Brink (2003) has also suggested a somewhat similar list of criteria for sets of indicators.

Table 23. Summary of agreement with OECD criteria.

	Policy relevance	Analytical soundness	Measurability	Interpretation
CBD	+	- - -	+++	++
OECD	+	- -	++	++
Wetterich	++	+	+	+
Extended set	+++	++	+	+
Restricted set	++	+	++	+++
Molecular diversity	++	+++	- - -	- - -

Policy relevance

The relevance for policy of the proposed sets of indicators can be compared in terms of the extent to which they address policy issues of international relevance. While all of the sets of indicators are relevant for policy, the larger sets proposed by Wetterich and this paper score somewhat better. The reason for this is that these sets also include indicators that attempt to assess the threats to genetic diversity (or the pressures behind genetic erosion). Thus Wetterich's set includes the indicators on the application of high-selective livestock breeding methods and the number of breeders' associations (and similar crop counterparts). The extended set improves on this assessment of pressures by including the indicators on number of breeding males of breeds characteristic for landscapes important for biodiversity, the area of low production/high biodiversity, and the percentage of seed originating on-farm. Furthermore, the extended list also includes the response indicators on *in situ* and *ex situ* conservation proposed by the OECD Expert Meeting, in addition to the supplementary indicator on characterisation of ex situ accessions proposed in this paper.

The restricted set proposed here receives a somewhat lower score because of the exclusion of some of the indicators of high policy relevance in the extended set, such as the number of endangered livestock breeds or crop varieties. The restricted set probably arguably has more policy relevance than Wetterich's set, despite the same scores of the two sets which is primarily a result of the rough scoring system pursued.

Indicators of molecular diversity score less well with respect to policy relevance because latent diversity is not observed by farmers who make the primary decisions concerning genetic diversity (Meng *et al.*, 1998). Furthermore international agreements and priorities have been formulated primarily in terms of apparent diversity i.e. livestock breeds and crop varieties. If indicators of molecular diversity are judged to be of ultimate interest with respect, say to analytical soundness, then they have to be complemented with indicators based on recognizable breeds and varieties in order to serve as a guide for priority setting and policy making.

Analytical soundness[10]

In the presentation in the previous section, attention focussed primarily on the analytical soundness of the various sets of indicators discussed. The indicators proposed by both the CBD and the OECD were seen to be lacking in their coverage of diversity concepts and priorities. These sets receive consequently the lowest scores for analytical soundness in Table 3. As was argued above, these sets rely on the number and share of livestock breeds and crop varieties which can increase simply through the ongoing development of new breeds or varieties that do not make use of any new genetic material. These indicators thus misrepresent the trends in genetic erosion. This was very

[10] This discussion of analytical soundness concentrates primarily on an assessment of the relative scientific validity of the proposed sets of indicators. The OECD Expert Meeting (2001) interprets analytical soundness as also based on international consensus and comparable across states. It is too early to assess the extent to which there is international consensus on such indicators. The comparability across states also raises some questions concerning the purpose of such a comparison. Given the diversity of agricultural systems found in different countries and the international nature of the plant and animal breeding industry, comparisons of such indicators across countries need to be used with caution. Nonetheless, indicators of genetic diversity should certainly be applicable in a standard manner in different countries.

clearly illustrated in the case study. For example, the number of wheat varieties in China has increased over time as modern breeding programmes have expanded but the underlying latent diversity has decreased somewhat. In the context of cross-national comparisons, the number of chicken breeds is higher in the Netherlands but corresponds to much lower genetic diversity than in Vietnam. Even if such comparisons are treated as irrelevant, it would seem clear all the same that the indicators based on counting breeds and varieties, as well as possibly their shares in production systems, present serious definitional problems (that is, practical problems) in a context where traditional breeds and landraces still account for a major share. A traditional breed or variety will typically be much more heterogeneous, and at the same time, there may not be any accepted definition of which members of a population fall under that breed or variety. In summary, the indicators based on number and shares of breeds and varieties are most suitable to improved breeds and varieties resulting from modern improvement programmes. But ironically, they still do not seem to be related to the aspect of genetic diversity of fundamental interest from the point of view of conservation and use of genetic diversity.

The indicators on number and share of breeds and varieties are arguably of interest, as they are they capture the units being managed, but they need to be complemented with additional ones. The OECD set does address this weakness to some extent by adding the indicator on the number and share of livestock breeds and crop varieties that are endangered.

The set of indicators proposed by Wetterich incorporates more additional indicators and thus scores better with respect to analytical soundness. In particular, Wetterich's set includes more attention for indicators of abundance and evenness of genetic diversity, in comparison to the set proposed by the OECD.

The extended set scores marginally better than Wetterich's set because of the additional indicators that address ecosystem diversity as well as species and genetic diversity (the various levels mentioned above). The restricted set, by virtue of the more limited set of indicators, is given a lower score comparable to that of Wetterich. These two sets are not however entirely comparable in terms of analytical soundness, given their different emphases.

Indicators of molecular diversity score the highest in terms of analytical soundness as they are the only direct means of measuring latent, as opposed to apparent, diversity. The diversity of genes, as measured at the molecular level, is of most interest when considering the erosion of genetic diversity. Most of the other sets of indicators concentrate on indicators of apparent diversity. Only the proposed extended and restricted sets include proxy indicators of latent diversity: the number of breeding males for high production as well as characteristic breeds, the percentage of seed originating on-farm, and the number of characteristic crop varieties stored in genebanks.

Measurability

Assessing the sets of indicators in terms of measurability, interpreted as the availability of data, yields a different ranking than the criteria of policy relevance or analytical soundness (see Table 3). The relatively simpler set proposed by the CBD scores the best, followed by the OECD set. The number of livestock breeds and the number of crop varieties dominate these sets and is information that is readily available in many countries, because of certification and regulatory requirements.

The set proposed by Wetterich and the extended set proposed in this paper are given a lower score for measurability. A number of the additional indicators included in these sets would require additional collection of data and thus monitoring efforts. One of the purposes of the case studies (next section) is to get some idea as to the challenges posed in this area. Indicators of molecular diversity pose by far the greatest challenge in terms of the availability of data, requiring many physical samples and analysis. In practice, such information is not readily available.

In general, the more extensive sets of indicators score less well on measurability. The restricted set proposed in this paper is comprised of a limited list of 6 indicators (covering both livestock and crops) and poses somewhat fewer challenges in terms of measurability. This is assessed as roughly equivalent to that of the OECD set, although the specific indicators are quite different in each set.

Interpretation

The final criteria suggested for assessing agro-biodiversity indicators relates to their ease of interpretation. To be effective tools for decision-making, indicators need to be clearly understandable by policy makers, other stakeholders in the area of agri-biodiversity, and the general public.

The number of indicators in a set is one clear aspect that contributes to that set's ease of interpretation. But this has to be considered along with how various stakeholders will interpret the indicators. Thus, the restricted set scores the highest in Table 3 although the list proposed by the CBD is comprised of even fewer indicators. This is because a number of stakeholders concerned with genetic diversity, for example non-governmental organizations or hobby farmers, are likely to question analytical soundness and policy relevance of the CBD list. This also applies for the somewhat longer set proposed by the OECD, which is given the same score as the CBD list.

The extended set in this paper and the set suggested by Wetterich both score lower because of the greater number of indicators involved. Furthermore, indicators such as the use high-selective breeding methods are more difficult for the general public to understand. Indicators based on molecular diversity are actually given a negative score on these grounds. Even many specialized policy makers would have difficulty understanding these indicators.

The criteria of interpretation places emphasis on having a limited, or core, set of indicators to facilitate general discussion and policy making. But this consideration can be taken too far. It is more likely that various sets of 'nested' indicators will be needed for various purposes and audiences, something about which little has been said up until this point. Policymakers at the highest levels of government require a concise set of indicators to summarize overall status and to set goals. The general public also needs a small set to be able to follow or participate in policy making processes. These are the main reasons behind the selection of only two indicators at COP7 (CBD, 2004). Policy analysts at lower levels formulate recommendations on allocation of resources and targeting of programmes that respond to pressures and changes in the state of genetic diversity. These policy makers require therefore a wider range of indicators for describing status at specific levels and identifying priorities. This more detailed monitoring and analysis inevitably feeds into the higher-level decision-making process so that it is incorrect to think that the two levels are unconnected.

There is a parallel with economic indicators. Economic policy is often communicated to the media and public according to a few indicators such as GDP growth, inflation and unemployment. And policy may also be evaluated in such relatively simple terms. But the more detailed consideration of circumstances and formulation of policy is based on a list of more detailed, or disaggregated, indicators.

For these reasons, the best situation may involve a core set that forms part of a broader set. This is the reason for proposing both an extended and restricted list, where the restricted set is a subset of the extended list. This proposal can also be viewed as an extended list of indicators, with a limited number identified as being more appropriate for summarising the situation with respect to genetic diversity and for formulating international agreements as well as national policies.

Conclusions

No single set of indicators scores better than the others according to the four criteria of policy relevance, analytical soundness, measurability, and interpretation. There are trade-offs between the sets of indicators reviewed with respect to the various criteria. The relative scores in Table 3 highlight these considerations. The extended and restricted sets may be better in terms of policy relevance but score less favourably in terms of measurability. The CBD set may be the easiest to measure, but its scientific basis can actually be perceived as negative i.e. not well-founded. At the other extreme, indicators of diversity at the molecular level are scientifically the most valid but pose almost insurmountable difficulties with respect to measurability or their interpretation.

The development of the extended and restricted sets in this paper are in fact based on an attempt to provide an alternative to these extreme trade-offs. The extended set builds on the contribution of Wetterich as well as that of the OECD, focussing particularly on improving the policy relevance and analytical soundness of the proposed indicators. Selecting a restricted set out of the extended set is an attempt to offer a set for which data is more easily available and that lends itself better to interpretation by a broader group of stakeholders.

6. Summary

National and international biodiversity strategies and policies require indicators to monitor status, trends, pressures and responses. Indicators for livestock and crop biodiversity have been proposed and discussed in a number of fora, including the Convention on Biological Diversity (CBD), the Organization for Economic Development and Co-operation (OECD) and the United Nation's Food and Agriculture Organization (FAO). Most of the indicators for livestock and crop biodiversity that are being given priority for further development, and concentrate primarily on the number (and possibly share) of livestock breeds/crop varieties. Most notably, discussions by the Subsidiary Body on Scientific, Technical and Technological Advice (SBSTTA) of the CBD, have concentrated on the number (and share) of livestock breeds and crop varieties.

However, the number of breeds/varieties is only weakly correlated to the state of biodiversity. One problem is that within breed diversity is ignored if only the number of breeds is counted. Furthermore, new breeds/varieties are constantly created, but the creation of a new breed/variety from old breeds varieties may not increase the amount of biodiversity. A related problem in the analysis of the state of biodiversity in crops and livestock is that the introduction of foreign material may increase local diversity, but does not increase biodiversity at a global scale. If local breeds/varieties are replaced by non-native high production breeds/varieties, biodiversity at the global scale is more likely to decrease. Thus, indicators of genetic diversity can perhaps best be interpreted in the context of assessing an individual country's contribution to diversity at the global level. It is the conservation (and use) of 'local' genetic diversity relative to a broader context, not just the amount of diversity present within a country, that is of interest here.

This report evaluates various proposed (sets of) indicators, which complement the basic indicators on number and share of breeds/varieties with additional indicators. This includes a set developed by the OECD (2001) and a set proposed by Wetterich (2003) To address the problems associated with those sets proposed by others, we propose two new sets of indicators, an 'extended set' and a 'restricted set'. The indicator sets were evaluated in four case studies (chicken in the Netherlands; chicken in Vietnam; wheat in the Netherlands; and wheat in China).

The *extended set* provides more indicators, so that a better assessment can be made of the state of biodiversity, and of pressure and responses as well. The extended set demands more, both of the person collecting the data, and the person interpreting the resulting indicators.

The *restricted set* focuses on a breed/variety breeds that is characteristic for landscapes or production environments important for biodiversity and characteristic for a region or country. By singling out one or two representative breeds/varieties (per species), one can have a single indicator that at a glance provides information on the state of agrobiodiversity.

The problem arising from the introduction of non-native material increasing biodiversity is avoided by concentrating on representative native breeds/varieties. Reliable indicators for diversity in high production breeds proved to be much harder to find. One problem is that diversity of high production breeds/varieties is not confined to single states, and should best be judged on a global scale. High production breeds of chicken in Vietnam and the Netherlands were to a large part the same and possibly the same applies to wheat in China and the Netherlands since both have been improved with American varieties. Analysis of DNA may be necessary to determine to what extent the globalisation has lead to a reduction of agrobiodiversity. Another question that may be resolved with DNA-analyses is how much diversity has been lost over time. For example, it is clear that in the Netherlands indigenous breeds have been greatly reduced, but to what extent diversity is lost is not clear.

The case studies indicate that measurement and interpretation of a large number of biodiversity indicators in crops and livestock is rather time consuming and country specific. Quality and availability of data is variable, which makes aggregation to regional or global levels difficult.

Besides testing of indicators in case study countries, indicators were further assessed in terms of their potential usefulness for policy formulation, implementation and monitoring, based on the criteria of policy relevance, analytical soundness, measurability and interpretation. One conclusion is that no single set of indicators performs better than the others when taking into account all four criteria, but different sets have advantages and disadvantages. The extended and restricted set may be better in terms of policy relevance but score less favourably in terms of measurability. The CBD set may be easiest to measure, but its scientific basis is actually questionable. It may be best to see these indicators on the number and share of breeds/varieties as serving in the measurement and calculation of other indicators. For example, determining an indicator such as the population size of native breeds necessitates the more basic data on what the breeds are; similarly determining the share of varieties of a given crop that are genetically homogeneous versus heterogeneous requires data on the number of varieties. At the other extreme, more comprehensive sets of indicators, including one or more indicators of diversity measured at the molecular level, are scientifically the most valid, but present more challenges in terms of measurability or interpretation.

National, regional and global policy makers together with biodiversity experts have to decide which indicators are desirable to effectively monitor status and trends in crop and livestock biodiversity. Consequently, (proxy) data on those indicators will have to be collected on a regular basis.

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