LEARNING ABOUT 2 5.1 5.2 INDICATORS

SDG Indicators 2.5.1 and 2.5.2 – Plant and animal genetic resources

Lesson 1: Introduction to plant and animal genetic resources

Text-only version

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Food and Agriculture Organization of the United Nations

SUSTAINABLE DEVELOPMENT GOALS

working for Zero Hunger

In this lesson

This lesson introduces Sustainable Development Goal (SDG) Indicators 2.5.1 and 2.5.2.

It presents the concept of genetic resources for food and agriculture. It describes the importance of conserving plant and animal genetic resources, and how this can be done. The main threats to plant and animal diversity are also examined.

The lesson introduces FAO information sources on plant and animal genetic resources and concludes with an explanation of important treaties and policy frameworks that govern these.

Learning objectives

At the end of this lesson, you will be able to:

- understand the importance of diversity for plant and animal genetic resources;
- describe the main threats to diversity;
- explain how these genetic resources can be conserved;
- describe plant and animal genetic resources;
- recognize policy instruments that govern these genetic resources.

Goal 2 and its targets

Goal 2 aims to End hunger, achieve food security and improved nutrition and promote sustainable agriculture.

Goal 2 is broken down into **eight different targets**. This course is concerned with…

Target 2.1	By 2030, **end hunger** and **ensure access by all people**, in particular the poor and people in vulnerable situations, including infants, **to safe**, **nutritious and sufficient food** all year round.
Target 2.2	By 2030, **end all forms of malnutrition**, including achieving, by 2025, the internationally agreed targets on **stunting and wasting** in children under 5 years of age, and **address** the **nutritional needs** of adolescent girls, pregnant and lactating women and older persons.
Target 2.3	By 2030, **double the agricultural productivity and incomes** of **small-scale food producers**, in particular women, indigenous peoples, family farmers, pastoralists and fishers, including through secure and equal access to land, other productive resources and inputs, knowledge, financial services, markets and opportunities for value addition and non-farm employment.

Target 2.4	By 2030, ensure **sustainable food production systems** and implement **resilient agricultural practices** that increase productivity and production, that help maintain ecosystems, that strengthen **capacity for adaptation to climate change**, extreme weather, drought, flooding and other disasters and that progressively **improve land and soil quality**.
Target 2.5	By 2020, maintain the **genetic diversity of seeds**, cultivated **plants** and farmed and domesticated **animals** and their related wild species, including through soundly managed and diversified **seed and plant banks** at the national, regional and international levels, and **promote access** to and fair and **equitable sharing of benefits** arising from the utilization of genetic resources and associated traditional knowledge, as internationally agreed.
Target 2.a	**Increase investment**, including through enhanced international cooperation, in rural infrastructure, agricultural research and extension services, technology development and plant and livestock gene banks in order to **enhance agricultural productive capacity** in developing countries, in particular least developed countries.
Target 2.b	**Correct and prevent trade restrictions and distortions** in world agricultural markets, including through the parallel elimination of all forms of agricultural export subsidies and all export measures with equivalent effect, in accordance with the mandate of the Doha Development Round.
Target 2.c	Adopt measures to **ensure the proper functioning of food commodity markets** and their derivatives and facilitate timely access to **market information**, including on food reserves, in order to help limit extreme food price volatility.

Target 2.5 Indicators

For each target, indicators have been defined. This course focuses on **Indicators 2.5.1** and **2.5.2,** which have been assigned to FAO as custodian UN agency.

Indicator 2.5.1 - Number of plant and animal genetic resources for food and agriculture secured in medium- or long-term conservation facilities

- The conservation of plant and animal genetic resources for food and agriculture (GRFA) in medium- or long-term conservation facilities (*ex situ* in genebanks) represents the most trusted means of preserving genetic resources worldwide. This indicator will measure progress towards Target 2.5.

Indicator 2.5.2 Proportion of local breeds classified as being at risk of extinction

- The indicator presents the percentage of livestock breeds among local breeds with known risk status classified as being at risk of extinction at a certain moment in time, as well as the trends for this percentage. The indicator will measure progress towards SDG Target 2.5.

What are plant and animal genetic resources?

Genetic resources for food and agriculture (GRFA) comprise the **diversity of plants, animals, aquatic resources, forests, micro-organisms and invertebrates.** They are the strategic reservoir on which all our food production systems depend. In this course, we will **focus on plant and animal diversity that is used for food and agriculture.** In this lesson, **crop and livestock wild relatives will also be discussed**.

It is important to know that food and agriculture systems also depend on other living resources, such as fish and other aquatic species, trees, microorganisms and invertebrates.

In the case of **plants**, estimates of the number of useful species vary. We use more than **6 100 agricultural and horticultural crop species**, but there are over **27 000 edible species**. In addition, nearly **18 000 plant species have medicinal uses**. Plant species are also used as textiles and building materials, and as gene sources, for environmental fuel and social uses. In the case of **livestock,** humans rely mainly on some **9 000 breeds** of about **40 animal species,** providing many products and services. These include food, wool, leather, manure, labour, cultural use, and landscape management.

Genetic diversity

All living beings, including plants and animals, are genetically diverse. Genetic diversity is **the variation in the genetic make-up among and within individuals, populations and species**. This variation results in the range of species, varieties and breeds that we use for food and in agriculture. Each organism has a **set of chromosomes** that contains its genetic information. Each chromosome consists of **DNA molecules**, which include the array of genes that are associated with various characteristics, or traits. Every individual is a **unique combination of genes**. **No two plants or animals have exactly the same genetic information** (except clones and identical twins). Each combination of genes contributes to **different traits or characteristics.**

For example, an animal with a certain combination of genes may, given suitable conditions, result in an animal being a high milk producer. There are three levels of genetic diversity:

1. Among species	
Genetic diversity among species in **plant** genetic resources. Barley VS. Maize	Genetic diversity among species in **animal** genetic resources. Sheep VS. Goat
2. Among populations of the same species	
Genetic diversity among populations of the same species in **plant** genetic resources. There are over 7 500 varieties of apple (*Malus pumila*) worldwide. The **Red Delicious apple** is a deep red colour and is known for its sweet flavour. It is a favourite snack for many. The **Granny Smith apple** is green in colour and has a tart flavour. It is a favourite for use in baking	Genetic diversity among populations of species in **animal** genetic resources. There are over 1 500 breeds of chickens worldwide. **Leghorn chickens** are white and are kept for laying eggs. **Plymouth Rock** chickens have barred plumage and are kept for both meat and eggs.
3. Among individuals of the same population	
For both plant and animal genetic resources, organisms produced through **sexual reproduction** are all **genetically unique** - **no two individuals are alike**. Only clones and identical twins are genetically identical. Within a variety or breed, these genetic differences among individuals are expressed as variation in traits. Trait variation within a population is due to both genetic differences among individuals and environmental influences. For example, in plants, differing amounts of inputs such as light, water and nutrients can also influence form and function.	

Let's take a look at two cases that highlight the importance of genetic diversity: one for plant genetic resources and the other for animal genetic resources. Bananas and pigs are just two of the many species that humans rely on for food, livelihoods, trade, industry and well-being.

CASE STUDIES

Plant genetic resources: The Cavendish banana

Supermarkets throughout the world mainly sell one type of banana: a large, sweet, yellow, seedless variety called "**Cavendish**". It accounts for nearly half the world's banana production and is by far the most widely traded variety.

These bananas are propagated vegetatively (by transplanting shoots) rather than through seeds. As a result, **all Cavendish bananas are genetically identical,** putting global banana **production at risk if a pest or disease outbreak to which this variety is susceptible occurs**.
The **Panama disease,** named after the country where it was first diagnosed, is attacking the Cavendish banana.

Caused by the TR4 strain of the fungus ***Fusarium oxysporum***, the disease attacks the roots and spreads to the rest of the plant, causing it to wilt and die. It is resistant to fungicide and cannot be controlled chemically. The Panama disease is now spreading throughout the world.
This is not the first time that a strain of this fungus has affected bananas. In the 1950s, the TR1 strain of the *Fusarium* fungus causing Panama disease devastated production of the then dominant variety, **Gros Michel**.

Producers had to replace their Gros Michel plantations, at great expense, with the Cavendish variety, which was resistant to the TR1 strain and thought to be resistant to the disease. However, a new strain of *Fusarium* (TR4) that attacks Cavendish plants has now emerged. As the Cavendish variety will eventually need to be replaced, scientists are working to find **a resistant variety with similar characteristics to the Cavendish**, which are appreciated by consumers.

Fusarium Wilt Tropical Race 4 (TR4)

www.fao.org/world-banana-forum/projects/fusarium-tr4/disease/en/

Animal genetic resources: Creole pigs in Haiti

Between 1978 and 1982, every **domestic pig** on the Caribbean island of Hispaniola, which includes both **Haiti** and the **Dominican Republic**, was killed to **fight an outbreak of African swine fever** (a severe disease affecting pigs).
Endemic in Africa, the disease threatened to spread to the rest of the Americas. The slaughter ended the outbreak, but it also **eliminated the native Haitian pig breed**.
The impact on farmers was huge. Poor farmers had used their native **Creole pigs** as an exchange for food and money: the animals converted scraps into meat, and farmers sold pigs to raise money.

Without pigs, the farmers' incomes fell. This severely affected their well-being and social activities in the country. For example, due to low incomes parents couldn't afford to send their children to school. The Yorkshire, Hampshire and Duroc pigs brought in to replace the native breeds were unsuitable: they required better feed, more pampering and veterinary treatments that were beyond the reach of poor Haitian and Dominican farmers. In 1983, French livestock specialists decided to recreate the old-fashioned Haitian pig. They crossed pigs from Guadeloupe (also in the Caribbean) with the Gascon, an ancient breed from France, and the Meishan, a prolific pig from China. By 1987 they were ready to distribute the pigs to farmers.

The farmers were pleased: the pigs looked like their original Creole animals, and - thanks to the Meishan - they produced more piglets even when poorly fed. By 1993 more than one-third of the pigs in Haiti were the new "old" breed.

A disease that can wipe out an important breed, breed population or variety could be a disaster for millions of people. The loss of even a minor breed or variety would be a loss of genetic diversity that may be important in the future.

Therefore, the conservation and sustainable use of **genetic diversity is of vital importance** for food and agricultural systems. There are inherent **risks in relying on a single variety of a crop or one breed of livestock.** Let us identify the dangers of relying on a narrow a gene pool.

Genetic vulnerability

Genetic uniformity within crops, varieties or breeds represents the following risks.

If **economic pressures** push farmers and livestock keepers to raise only a certain type of plant or animal, the result can be catastrophic.

Production systems that are highly specialized and rely on one crop, variety or breed tend to be particularly **vulnerable to pest** and **disease outbreaks** and **extreme environmental conditions** such as flooding or drought. Crops that are **vegetatively propagated** are particularly prone to these risks because individuals of a given variety of these species are **genetically identical**.

Vegetatively propagated crop

Sweet potatoes grown from tubers are an example of vegetatively propagated crops. Cassava, rubber and banana are further examples.

In this context, breeders need easy **access to well documented materials**, which can be **screened for sources of resistance or tolerance** necessary to address issues resulting from genetic vulnerability.

Examples of the effects of reduced genetic diversity for crops and livestock

PLANT GENETIC RESOURCES: CROPS

- South American leaf blight, caused by the fungus *Microcyclus ulei*, is a serious disease of the **rubber tree** (*Hevea spp.*). In Brazil, the centre of origin of the rubber tree, the disease prevents the use of plantations to produce latex. As a result, almost all the world's natural rubber is produced in Asia and Africa, where the pathogen is presently absent. *Hevea* trees in Asia and Africa are also susceptible to the fungus. **Strict controls on freight and flights** between Brazil and tropical Asia and Africa are therefore crucial, to avoid the introduction of the fungus.
- Lack of varietal diversity, as well as increases in the use of pesticides and fertilizers, have resulted in severe outbreaks of **brown planthoppers** (*Nilaparvata lugens*), a tiny insect that sucks the rice plant's sap and transmits viruses that stunt its growth. The solution has been to cut pesticide use and use integrated pest management techniques, and to find rice varieties that are resistant to the insect and to the viruses it transmits.
- Cassava mosaic virus causes a serious disease that affects **cassava**, a key crop for food security in central and western Africa. The disease spreads via infected cuttings or through whiteflies (*Bemisia tabaci*). First reported in 1894, the disease has caused periodic famines. In 1974, the International Institute of Tropical Agriculture released a resistant cassava variety. However, in the late 20th century a more virulent strain of the virus broke out and spread quickly in East and Central Africa. Scientists and farmers are trying to control the disease by **eliminating infected plants and finding new resistant varieties**.
- Stem rust, caused by the fungus *Puccinia graminis*, has long plagued **wheat crops**. Successive outbreaks of the disease had disastrous consequences on food security and contributed to the weakening of the Western Roman Empire, which eventually fell. In 1999, a virulent strain of rust emerged in Uganda and is spreading across Africa and Asia. Scientists are now trying to **incorporate resistance into the wide range of wheat varieties** grown in this region.
- In 1970, an epidemic of **southern corn leaf blight**, caused by the *Bipolaris maydis* fungus, destroyed about 15 per cent of the **crop production** in the US Corn Belt, with an estimated monetary loss of 1 billion US dollars. **The development of resistant varieties** and improved crop

management has **reduced the incidence of the disease** in the United States, but it is still a major problem in the tropics.

- **Grape and wine production** in Europe and other wine producing areas is threatened by Grape phylloxera (*Daktulosphaira vitifoliae*), a tiny insect that feeds on the leaves and roots of the grapevine. The resulting **root galls**, knot-like swellings on the rootlets, may lead to decay of infested parts. Smaller galls can occur on leaves, reducing photosynthesis and inducing premature defoliation. In the late 19th century, an epidemic of grape phylloxera **eradicated up to nine-tenths of the vineyards** in Europe.
- Between 1845 and 1852, a catastrophic event known as the **Irish potato famine** resulted in the **death of one million people** from starvation and the migration of another million. One of the causes that led to this tragedy was the **over reliance on a single variety of potato**, the Irish Lumper. This variety was susceptible to **late blight disease** caused by *Phytophthora infestans*, a fungus that attacks potato tubers. The disease resulted in losses up to two-thirds of crop production in Ireland.

ANIMAL GENETIC RESOURCES: DOMESTICATED ANIMALS

- The **European honeybee**, *Apis mellifera*, is susceptible to a mite known as *Varroa destructor*. This parasite infests bees and spreads viruses that may kill a bee colony.
  Beekeepers control the mite using chemicals, but this limits the development of natural resistance in the colony.

  Bee races in Africa are resistant, but are more aggressive - so much that they are known as **killer bees**. A few colonies of European bees have been found to have naturally developed a higher tolerance to the mites. This shows the importance of having **genetic diversity to adapt to specific challenges**.

- **Porcine stress syndrome** is linked to a genetic defect in some common breeds of **pigs**. Pigs expressing this defect are even more susceptible to stress.

  When they are being transported, **pigs** may suffer from severe stress, become overheated, and die. The meat from stressed animals is pale, soft, and exudes water. Economic losses from porcine stress syndrome in the United States are estimated at USD 90 million a year.

  Breeding pigs for higher lean meat content inadvertently selected for the defective gene.

  DNA analysis shows that **this gene probably came from a single breeding founder animal.**

- The black-and-white Holstein-Friesian is the world's most widely used type of **dairy cattle**. But it is highly inbred. Artificial insemination makes it possible to produce thousands of offspring from a single bull.

  Today, almost all Holsteins in the United States are descended from two bulls from the 1960s. These bulls were called the "Pawnee Farm Arlinda Chief" and the "Round-Oak Rag Apple Elevation". While breeding from superior sires has greatly boosted milk production, it leaves the breed dangerously exposed to random increases in the frequency of inherited disorders.

  For example, descendants of "Pawnee Arlinda Chief" inherited a genetic defect that **causes spontaneous abortions**.

  Up to 500 000 abortions have cost the US dairy industry USD 420 million.

Genetic adaptation to different environments

Farmers and livestock keepers encounter a **vast array of situations and conditions** that can affect their crops and livestock.
Livestock are raised everywhere from the humid tropics to deserts to polar tundra.
Livestock keepers can be backyard farmers or pastoralists who trek with their herds over hundreds of kilometers in search of pasture and water, to highly intensive livestock production systems.
Farmers grow crops in irrigated wetlands and semi-arid steppes, on hillslopes and valley bottoms, on light, sandy and on heavy clays. Some farmers cultivate thousands of hectares and supply international markets. Many more are subsistence smallholders, who grow food to feed their families. Adaptation to these varied conditions will require crop varieties and animal breeds with different gene combinations
Crops and livestock need to be well adapted to a wide range of conditions. **Each set of environmental conditions requires a different crop variety or livestock breed**, which means a **different combination of genes**. A plant variety or animal breed that thrives in one environment may fail miserably in another. Over centuries and millennia, farmers and livestock keepers have selected and bred varieties and breeds that are uniquely **adapted to specific conditions**. Some tolerate drought, others grow well in wet or saline conditions, and still others are tolerant to particular pests and diseases. **Without genetic diversity, it would be impossible to grow crops or raise livestock in varied environments**, including marginal areas such as high altitudes, steep slopes, semi-arid lands, areas prone to flooding, or on saline soil.

Rice

Rice grows in a wide range of conditions:

- Dry land: "upland"
- Irrigated: "wetland" or "lowland"
- Deep water

Some rice varieties can tolerate flooding of a metre or more: their stems elongate and the foliage floats on the water surface. Some varieties of rice thrive at sea level and others at over 3 000 metres in the Himalayas of Nepal.

Yak

Yaks are a hardy bovine species found from the Himalayas of Nepal to the plateau of Tibet, Mongolia and Siberia.

They are well adapted to the extreme cold and to high altitudes. They have larger lungs and hearts than cattle, a thick layer of fat under the skin, and long hair.

Why is genetic diversity important?

Here are several reasons that support the need for a diverse genetic base.

FOOD PRODUCTION	Different species, varieties and breeds are adapted to different environments and production systems. Their genetic diversity makes it possible to **produce food in a wide range of conditions**.
FOOD SECURITY	Crop and livestock diversity have multiple roles to play in ensuring food security, as a **source of food and livelihoods**, and by providing farmers and livestock keepers with more options that can enhance their income generation and development.
SURVIVAL AND ADAPTABILITY	Genetic diversity makes it possible for a species to survive and **adapt to a changing environment**. Genetic mutations, and the recombination of genes through sexual reproduction, create **variation within populations**. The more diverse a population is, the more likely that some of its individuals will be able to survive changes in their environment and pass the adaptive traits on to their offspring. This process is known as **natural selection**. It can take many generations to establish an adaptive trait in a population. Genetic diversity is especially **important in the face of climate change.**

DIET AND NUTRITION	Nutritionally, we need a **diverse diet** consisting of different types of plant and animal products.
PESTS AND DESEASES	Pests and diseases are **constantly evolving**. Genetic diversity reduces the threat of epidemics and makes it possible to combat pests and diseases in various ways: • using existing, better adapted varieties or breeds; • developing new varieties or breeds; and • growing or raising a number of different varieties, breeds or species in the same location.
OTHERE SERVICES	Livestock **not only provide food,** but also many other products and services. These include textiles, leather, draught power, transport, recreation, landscape maintenance and ecosystem services (such as supplying manure).
INSURANCE FOR THE FUTURE	We do not know what the future will bring. **Climate change** is predicted to have a significant impact on agriculture, including raising temperatures, limiting crop productivity and reducing water availability in some regions while increasing extreme events such as flooding. Genetic resources and their diversity are essential for **adaptation to climate change** and any **other challenges** that might occur in the future.
CONSUMER DEMANDS	Consumer demands are constantly changing. A shift to a new type of food means that we need species, varieties and breeds with different characteristics.

Wild relatives of crops and livestock

All our crops and livestock are descended from wild plants and animals. Crop and livestock wild relatives contain valuable genes and traits that breeders can potentially incorporate into domesticated crops or livestock. These species are most often found in those regions where domestication originally occurred.

Potato *(Solanum tuberosum)* - There are 151 known species of wild potato, distributed from the southern United States to southern Chile. Many of them are inedible, but they may have **valuable traits for modern breeding**. These species are threatened by habitat loss and a warming climate;

about 13 are at risk of extinction. The International Potato Center (CIP) in Peru is collecting specimens of these wild species to conserve in its genebank.

Banteng cattle (*Bos javanicus*) - The banteng is a wild species of cattle native to Southeast Asia. It is thought to be the ancestor of the Bali cattle, a common domesticated species in Indonesia. Wild banteng cattle **are endangered** by habitat loss, hunting, hybridization with domestic cattle and infections with cattle diseases. Scientists are exploring the use of artificial insemination to **incorporate banteng traits into domestic cattle.**

Sugar beet (*Beta vulgaris ssp. vulgaris*) - Populations of *B. vulgaris* subsp. *maritima* (a wild relative of sugar beet) have been crossed with sugar beet varieties to produce plants that are resistant to powdery mildew, a major disease for this crop. European populations of this same wild relative have been found to show high levels of resistance to rhizomania, or "crazy root", caused by the virus *Erwinia carotovora* subsp. *betavasculorum.* These populations could provide new sources of resistance to this disease and be transferred into sugar beet.

The tabs below provide information on crop and animal wild relatives that are listed by the International Union for Conservation of Nature's Red List (IUCN), www.iucn.org/,as under threat.

CROP WILD RELATIVES	According to the IUCN, **many wild plant species, including crop wild relatives and wild food plants, face an elevated risk of extinction** due to habitat destruction, overharvesting and climate change. The number of crop wild relative species listed by IUCN as threatened: 3 wild rice species; 3 wild wheat species; 3 wild yam species. The number of crop wild relative species listed by IUCN as endangered: 4 mango species; 1 wild chickpea species.
LIVESTOCK WILD RELATIVES	As there are few domesticated animal species, the range of wild relatives is limited. Some of the animal wild relatives are under threat. According to the IUCN: 44% of the wild relatives of sheep and goats are at risk of extinction. In comparison with 21 percent of all mammal species: 50% of the wild relatives of pigs are at risk of extinction; 83% of the wild relatives of cattle are at risk of extinction.

Breeding

Breeding approaches have resulted in well adapted crop varieties and livestock breeds. Breeders have drawn on **various approaches**. The basic elements always include the following:

- Decision on the breeding goal (improved production, hardiness, etc.)
- Choice of measurable traits
- Selection of the best individuals
- Production of the offsprings of the selected individuals

This approach leads to a **change in the genetic make-up over generations**, with the aim of reaching a given goal.

Threats to genetic diversity

This course emphasizes the importance of **genetically diverse plants and animals**. However, this diversity is threatened by a number of factors.

1. **Intensive farming**	
Plants - Crops	**Animals - Livestock**
As farming becomes larger scale and more intensive, it can lead to **monoculture**, where only a single crop, or even a single variety, is grown.	As farming becomes larger scale and more intensive, it **tends towards highly specialized production** (e.g. only milk). Big livestock farms often keep only one species of animal, and a single, specialized breed; traditional breeds tend to be multi-purpose.
2. **Yield and productivity**	
Plants - Crops	**Animals - Livestock**
Under the right conditions, **modern varieties produce higher yields** than traditional types, though they often **require more inputs such as fertilizer and pesticides**. The introduction of modern varieties marginalizes and reduces the cultivation of farmers' varieties/landraces.	Under the right conditions, **modern breeds are more productive** than traditional breeds, even though they may **require special feed, housing and veterinary care**. Livestock keepers reduce the use of traditional.
3. **Mechanization**	
Plants - Crops	**Animals - Livestock**

Mechanization **requires that crops grow evenly** and are **sown and harvested all at the same time**. Farmers' varieties/landraces are often unsuited to these technologies	Tractors and motor vehicles have largely **replaced draught animals**, such as horses, oxen, camels and water buffalo.
4. Agrochemicals	
Plants - Crops	**Animals - Livestock**
Many modern, improved crop varieties **respond to fertilizer applications**, leading to **increased yields**. Farmers' varieties/landraces that do not respond as well will have lower yields, so farmers often stop growing them. Varieties can be genetically tailored so that pesticides can be sprayed without harming the plants. This **process is expensive and time consuming,** and is **only used on high yielding modern cultivars.**	Not applicable
5. Uniform products	
Plants - Crops	**Animals - Livestock**
Supermarkets require reliable deliveries of uniform products. Products of farmers' varieties/landraces tend to be more variable, so often do not find a large-scale market	**Supermarkets require reliable deliveries** of uniform products. Traditional breeds tend to be more variable, so often do not find a large-scale market.
6. Seed supply/Artificial insemination	
Plants - Crops	**Animals - Livestock**
Commercial seed suppliers sell a few modern varieties. Suppliers of registered farmers' varieties/landraces are limited.	Commercial insemination services mainly **provide semen of a few modern breeds**.
7. Inbreeding	
Plants - Crops	**Animals - Livestock**
Not applicable.	Inbreeding is **reducing the genetic diversity** of both rare breeds (where there are too few breeding animals) and some commercial breeds

	(where intensive selection means a few males sire a large proportion of the animals).
8. Introduced varieties and exotic breeds, uncontrolled crossbreeding	
Plants - Crops	**Animals - Livestock**
Improved varieties **are replacing farmers' varieties/landraces** with a consequent increased risk of losses of genetic diversity in the field.	Exotic breeds are **replacing traditional breeds** or are **diluting the native germplasm** through **uncontrolled crossbreeding**: unplanned breeding that does not try to monitor and conserve the local populations.
9. Pests and diseases	
Plants - Crops	**Animals - Livestock**
Globalization and climate change are increasing the risk of **pests and diseases spreading to new areas.**	Globalization and climate change are increasing the risk of diseases spreading to new areas. Diseases may **kill susceptible breeds**, and efforts to control diseases may lead to **the culling of more animals**.
10. Loss of habitat and climate change	
Plants - Crops	**Animals - Livestock**
Environmental degradation, land clearing and climate change are **reducing the population sizes and distribution of crop wild relatives**.	Loss of pasture land through land-use changes is **reducing the pasture area available to feed livestock**. Increasingly extreme weather events may **kill many animals**.
11. Policies	
Plants - Crops	**Animals - Livestock**
Policies that only **tend to favour a few modern varieties** and neglect farmers' varieties/landraces pose threats to genetic diversity.	Policies that only **tend to favour a few modern breeds** and neglect traditional breeds pose threats to genetic diversity.
12. Lack of awareness	
Plants - Crops	**Animals - Livestock**
Extension services, educational institutions, farm advisors and seed suppliers are often	**Policy-makers, extension services, educational institutions, farm advisors and veterinarians** are

not aware of the value and importance of farmers’ varieties/landraces.	often not aware of the value and importance of traditional types. They tend to **favour modern breeds**.

FAO Terminology for Plant Genetic Resources

The terms below are used to identify methods of conserving plant genetic resources.

***In situ* conservation of crop wild relatives and wild food plants**	*In situ* conservation involves the location, designation, active management and monitoring of target plant populations within their natural habitats.
On-farm management of farmers’ varieties/landraces	On-farm management of farmers’ varieties/ landraces is referred to as all practices for the conservation and sustainable use of these genetic resources within the agricultural systems in which they have evolved.
***Ex situ* conservation**	The conservation of biological diversity outside its natural habitat. It includes storing of orthodox seeds in seed genebanks; maintaining live plants in a field genebank; *in vitro* culture (plant tissue explants conserved in a sterile environment and a nutrient medium); cryopreservation (the storage of plant organs, such as buds, shoot tips, other meristematic and embryonic tissue, in liquid nitrogen); pollen banks and DNA banks.

FAO Terminology for Animal Genetic Resources

The terms below are used to identify methods of conserving animal genetic resources.

***In situ* conservation**	Conservation of a breed through continued use by livestock keepers in the production system in which the livestock evolved or are now normally found and bred.
***Ex situ* conservation**	In the context of domestic animal diversity, *ex situ* conservation means conservation away from the habitat and production systems where the resource developed. This category includes both the maintenance of live animals and cryoconservation.

***In vivo* conservation**	Conservation of a breed through maintenance of live animal populations. It encompasses both *in situ* conservation and *ex situ in vivo* conservation.
***Ex situ* in vitro: Cryoconservation**	Conservation by cryopreservation of a breed's genetic material (usually semen, embryos or somatic cells) in vitro, in a non-living state, so that live animals can, if necessary, be reconstituted in the future. This type of conservation is also called *ex situ in vitro* conservation.
***Ex situ in vivo* conservation**	Conservation of a breed through maintenance of live animal populations not kept under normal management conditions (e.g. zoological parks and in some cases government farms) and/or outside the area in which they evolved or are now normally found.

There is often no clear boundary between in situ and *ex situ in vivo* conservation and care must be taken to describe the conservation objectives and the nature of the conservation in each case.

Similarities and differences between the conservation of plants and animals

There are similarities and differences between the conservation of crops and livestock. The differences between plants and animals mean that **different conservation approaches are needed.**

Similarities	Differences
• Both may be preserved either as **living organisms** or as material that can be used to produce plants (seeds, tissues, pollen) or animals (embryos, semen). • They may be preserved in their **native habitat** (*in situ*) or elsewhere (*ex situ*). • Both can be conserved by **farmers or livestock keepers**, or in **specialist genebanks**.	• Plant materials (especially seeds) are easier to **collect and store** than animal genetic materials. • There are many **more species and varieties** of crops than there are species and breeds of livestock. • **Genebanks** for storing plant genetic resources are more widespread than those for animals.

Summary approaches for conservation of plant genetic resources

Different approaches are used when conserving **plant genetic resources**. These depend on whether they are conserved as **whole plants, seeds** or as **other reproductive material.**

Whole plants			
Term	*In situ* conservation	On-farm management	Elsewhere (*ex situ* as whole plants)
Description	Protecting crop wild relatives and wild food plants in their natural habitats	Farmers maintain local crops, farmers' varieties and landraces in their farms and gardens	Maintaining plants in field genebanks
Explanation	N/A	N/A	Used especially for **fruit trees, vegetatively propagated species** (e.g. roots and tubers), and for species that produce recalcitrant seeds (such as onions), where the seeds are difficult to conserve. Annual crops must be resown or replanted each year

Seed		
Term	*Ex situ* in a seed genebank	
Description	**Medium-term storage**: 2-4°C, low moisture content	**Long-term storage**: -20°C or lower, low moisture content
Explanation	Storing dried seed under refrigerated conditions can maintain viability. Mainly used for active collections, where the seed is stored for distribution to users. May also be used for base collections when long-	For long-term storage, dried seed is maintained at -20°C or below. This method of storage is for base collections, where the emphasis is on conservation rather than direct use. Seeds can remain viable for many decades.

	term facilities are lacking or insufficient. Periodically, a small subsample of each accession is tested for viability. If the viability falls below a threshold level, the seed is regenerated to collect fresh seed for storage.	Periodic germination tests are conducted to assess viability.

Other reproductive material conserved *ex situ*				
Term	*In vitro* culture	Cryopreservation	Pollen	DNA
Description	Plant tissue explants conserved in a sterile environment and a nutrient medium	Deepfrozen in liquid nitrogen	In a pollen bank	In a DNA bank
Explanation	The seeds of some plants do not survive drying or freezing. These include many fruit tree species and plants that produce roots, tubers, bulbs or oily seeds (such as groundnuts). Such **recalcitrant species** are usually conserved as living collections, or via *in vitro* culture or cryopreservation.		N/A	N/A

Different approaches are used when conserving **animal genetic resources**. These depend on whether they are conserved as **live animals** or as **reproductive material.**

Live animals (*in vivo*)	Reproductive material (*ex situ in vitro*)
Native habitat (*in situ in vivo*) These animals are conserved on a farm, in the field or in a protected area.	**Reproductive materials (*ex situ in vitro*) include:** • semen • oocytes (immature eggs) • embryos • somatic tissue (body tissue)
Elsewhere (*ex situ in vivo*) These animals are conserved in a similar habitat, but in a different location from its	

origin. They are also conserved at breeding stations or zoos.	**These materials are conserved in genebanks that provide cryoconservation.**

Collecting plant and animal genetic resources

When collecting plant and animal genetic resources, it is **important to collect samples** from the areas where **particular crops or livestock first evolved or were domesticated**. This is because, the biodiversity is usually highest in such places, and there may be many wild relatives with potentially valuable traits. In addition, collection samples should be collected in areas where many farmers grow farmers' varieties/landraces, or livestock keepers raise traditional breeds as they are more threatened and likely to be replaced.

Major centres of livestock domestication – based on archaeological and molecular genetic information

(1) turkey (2) guinea pig, llama, alpaca, (3) pig, rabbit (4) cattle, donkey, (5) cattle, pig, goat, sheep, Bactrian camel (6) cattle, goat , chicken, river buffalo, (7) horse, (8) yak, (9) pig, swamp buffalo, chicken, (10) chicken, pig, Bali cattle (11) dromedary, (12) reindeer.

Plant genebanks

Genebanks that hold plant genetic resources are found all over the world. Here are some international, regional and national organizations that hold these valuable genetic resources.

International

Major international collections of plant genetic resources are held in all regions of the world. The eleven international CGIAR genebanks currently hold more than750 000 **accessions**[1] of major food and feed crops. These crops range from rice and wheat to legumes and potatoes.

[1] An accession is a sample of seeds, planting materials or plants, representing a wild population, a farmer's variety or landrace, a breeding line or an improved cultivar, which is conserved in a genebank.
Each accession should be distinct and, in terms of genetic integrity, should be as close as possible to the sample originally provided.

Their collections are held in trust for the benefit of the international community. These collections hold most of the diversity of the staple crops key for food security.

CGIAR genebanks and germplasm health units:
www.genebanks.org/genebanks/

Regional

Many countries have decided to combine their collections for long-term conservation.

This regional approach has been successfully implemented in several regions.

Examples of regional conservation facility:

- ✓ **CATIE**

  The regional conservation centre for Central America and the Caribbean is located in Costa Rica.

  Collections and Germplasm Banks (CATIE):

  www.catie.ac.cr/en/products-and-services/collections-and-germplasm-banks

- ✓ **NordGen**

  The regional conservation centre in Europe for the Nordic countries is located in Sweden.

  Nordic Genetic Resource Centre (NordGen):

  www.nordgen.org/en/

- ✓ **SADC Plant Genetic Resource Centre**

  The regional conservation centre in the Southern African Development Community is located in Zambia.

  www.sadc.int/sadc-secretariat/services-centres/spgrc/

- ✓ **CePaCT**

  The regional conservation centre for the South Pacific is located in Fiji.

  Centre for Pacific Crops and Trees (CePaCT):

  https://lrd.spc.int/the-centre-for-pacific-crops-and-trees-cepact

National

Many national research organizations **maintain seed and field genebank *ex situ* collections of crops**.

Examples of genebank in three locations:

- ✓ **USDA-ARS National Center for Genetic Resources Preservation, United States of America**

  Its vaults in Fort Collins, Colorado hold collections of seeds, clones, animals and microbes.

  These collections are listed in the Germplasm Resources Information Network database.

  https://data.nal.usda.gov/dataset/germplasm-resources-information-network-grin

- ✓ **Ethiopian Biodiversity Institute**

This is one of the oldest and largest national seed banks in sub-Saharan Africa.
During the droughts in the 1980s, the institute provided grains in exchange for farmers' seeds. The seeds were then returned once the drought had ended.
www.ebi.gov.et/about-us/

- ✓ **The National Bureau of Plant Genetic Resources (NBPGR), India**
  The NBPGR holds one of the largest germplasm collections in the world. The Bureau has its headquarters in New Delhi and has a network of 10 regional stations, each focusing on specific groups of crops.
  www.nbpgr.ernet.in/

Duplicate collections of genetic resources

A common recommended practice for well managed genebanks is to **store duplicates of their collections in different locations**. Some collections of safety duplicates, such as field and *in vitro* collections, are managed by the holding genebank in a similar manner as their own collections.
Other safety duplicates are managed as a **black box**, where the hosting genebank merely maintains the seed samples but does not manage them. **Only the depositor has the right to access the seeds.**
In 2008, an initiative led by the Norwegian Government and the Global Crop Diversity Trust established the **Svalbard Global Seed Vault**, a **black box repository** of germplasm collections.
The vault is located in Spitsbergen in the Svalbard islands of Norway, some 1 300 kilometers within the Arctic Circle.
It currently holds over 960 000 seed samples. It is a repository of black box collections from donor genebanks, and has a capacity of 4.5 million samples.

ICARDA retrieves black box collection from Svalbard Global Seed Vault
The International Center for Agricultural Research in Dry Areas (ICARDA), near Aleppo, had to cease operations in Syria due to the civil war.
Fortunately, ICARDA had safety duplicated most of its seed collections at the Svalbard Global Seed Vault.
ICARDA has since retrieved its black box collection of some 38 000 seed samples, which were sent to Lebanon and Morocco to re-establish ICARDA's active collections.
Sixty-five percent of these collections are unique landraces and wild relatives of cereals, legumes and forages collected from regions such as the "Fertile Crescent" in Western Asia.

Animal genebanks

Ex situ in vitro genebanks are **less common for livestock than for plants**. This is because livestock conservation has focused much more on *in situ in vivo* conservation. Two major reasons for this are given here.

Collection difficulty	It is easy to collect plant seeds, but harder and more expensive to collect semen and embryos from animals.
Cost and difficulty of storage	Many seeds can be dried and stored for years, but semen and embryos must be deep-frozen and stored in liquid nitrogen at −196 °C. This process is more complicated and expensive.

Nevertheless, more than 60 countries have **national** livestock genebanks. Some **NGOs** run their **own genebanks** and/or **focus on *in vivo* conservation**. More information is provided below.

National

National Center for Genetic Resources Preservation, USA

Located in Fort Collins, Colorado, this centre holds both plant and animal germplasm.

It has the world's largest collection of genetic material from livestock, with nearly 1 million samples from 31 000 animals belonging to 26 species. The collection includes conventional livestock such as pigs, chickens and cattle, farmed fish such as trout, as well as bison, elk and yaks.

NGOs

Rare Breeds Survival Trust, United Kingdom

The Rare Breeds Survival Trust has a genebank that maintains a collection of livestock germplasm. This includes semen of rare breeds of cattle, sheep, goats, equines and pigs, and embryos of cattle, goats and sheep. This genebank was created after an epidemic of foot-and-mouth disease in 2001 that exposed the risks of relying only on *in vivo* collections.

NGOs (*in vivo only*)

NGOs focusing only on *in vivo* conservation

- **Society for the Conservation of Old and Endangered Livestock Breeds** (Gesellschaft zur Erhaltung alter und gefährdeter Haustierrassen) located in Germany, www.g-e-h.de/
- **The Livestock Conservancy** located in the United States of America, http://livestockconservancy.org/

Information sources on plant genetic resources

The **World Information and Early Warning System on Plant Genetic Resources for Food and Agriculture (WIEWS)** www.fao.org/wiews/en/ , is the FAO information system on plant genetic resources. It includes information on:

- Over 17 000 national, regional and international institutes and organizations dealing with the conservation and sustainable use of plant genetic resources
- More than 4.9 million accessions from over 51 000 species conserved under medium- or long-term conditions in over 570 genebanks from 90 countries and 16 international/regional centres
- More than 20 000 cultivars
- More than 19 000 publications

WIEWS is a source of information **for SDG Indicator 2.5.1**. This indicator focuses on the conservation of plant genetic resources.

For more information on WIEWS, go to Lesson 2 of this course.

Information sources on animal genetic resources

The **Domestic Animal Diversity Information System (DAD-IS)** www.fao.org/dad-is/en/ , is the **global information system** on animal genetic resources for food and agriculture. It is hosted by FAO.

This database currently contains information on 38 species and on about 8 800 breeds in more than 180 countries. DAD-IS contains information on:

- Breeds and breed diversity and breed risks of extinction
- References on animal genetic resources
- Contact details of national organizations involved in the management of animal genetic resources

DAD-IS is the source of information for SDG Indicators 2.5.1 and 2.5.2. These indicators focus on the conservation of animal genetic resources.

For more information on DAD-IS, go to Lesson 5 of this course.

Key policy instruments, frameworks and documents

Various international policy instruments and frameworks are important for fulfilling the goals that national governments have set themselves for the conservation and sustainable use of agrobiodiversity.

Commission on Genetic Resources for Food and Agriculture

The Commission on Genetic Resources for Food and Agriculture, www.fao.org/cgrfa/en/ , is an intergovernmental forum, established in 1983, with 178 members and is hosted by FAO.
It aims to ensure the conservation and sustainable use of genetic resources and the fair and equitable sharing of benefits from their use.

Tasks include:

- developing and overseeing policies and initiatives to raise awareness and solve problems;
- preparing global assessments of genetic diversity, threats and conservation measures; and
- negotiating global action plans and codes of conduct.

State of the world reports

These reports are summaries of the current situation for crops and livestock. They are prepared by FAO at the request of national governments.

For plants:

- First report, 1996
  www.fao.org/3/a-w7324e.pdf
- Second report, 2010
  www.fao.org/docrep/013/i1500e/i1500e.pdf

For animals:

- First report, 2007
  www.fao.org/docrep/010/a1250e/a1250e00.htm
- Second report, 2015
  www.fao.org/3/a-i4787e.pdf

Global plans of action

These are plans of action that have been agreed by governments for the conservation and sustainable use of genetic resources.

Plant Genetic Resources:

The First Global Plan of Action was adopted by member countries in 1996.
The Second Global Plan of Action, www.fao.org/docrep/015/i2624e/i2624e00.pdf , was adopted in 2011 and is an update of the first Global Plan of Action. It supports implementation of the International Treaty on Plant Genetic Resources for Food and Agriculture.

Animal Genetic Resources:

The Global Plan of Action, www.fao.org/3/a-a1404e.pdf , was adopted in 2007.

International Treaty on Plant Genetic Resources for Food and Agriculture

The International Treaty on Plant Genetic Resources for Food and Agriculture, www.fao.org/plant-treaty/en/ , is a multilateral legally binding agreement that was adopted in 2001, but came into force in 2004. The Treaty:

- recognizes the contribution of farmers to crop diversity;
- establishes a multilateral system to provide access to plant genetic materials; and
- establishes a fund for sharing the benefits derived from the use of PGRFA.

There is no equivalent treaty for animals.

Convention on Biological Diversity

The Convention on Biological Diversity, www.cbd.int/ , is a multilateral convention that entered into force in 1993 with 168 signatories. Its goals include:

- Conserving biological diversity;
- Sustainable use of its components; and
- Fair and equitable sharing of benefits.

Summary

SDG Indicator 2.5.1 refers to the number of plant and animal genetic resources for food and agriculture secured in either medium- or long-term conservation facilities.
SDG Indicator 2.5.2 refers to the proportion of local breeds classified as being at risk, not at risk, or at unknown level of risk of extinction.

Genetic resources for food and agriculture are the basis for sustainable agriculture and food security. This genetic diversity determines the range of characteristics that enable plants and animals to fulfil different roles in agricultural production systems and adapt to changing environmental conditions, such as extreme temperatures, drought, flooding and outbreaks of pests and diseases.

Plant genetic resources can be conserved in genebanks (*ex situ*). Others need to be conserved in agricultural production systems (on-farm) or in natural or semi-natural habitats (*in situ*).

Animal genetic resources are conserved on a farm, in the field or in a protected area Native habitat (*in situ in vivo*), in a similar habitat but in a different location than its origin (*ex situ in vivo*) or as reproductive material in genebanks that provide cryoconservation (*ex situ in vitro*).

FAO assists governments by coordinating forums, maintaining databases and compiling periodic reports on the status of genetic diversity, and supporting the implementation of global plans of action for conservation.