

Seed, species diversity and seed databases

A transdisciplinary review

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Abstract

Seed is at once a biological object, a legal object, a data record and a cultural heritage. Anyone seeking to describe the conservation of plant genetic diversity cannot manage with only one of these four perspectives. This paper places the four layers side by side, shows the points at which they meet, and names the contradictions that become visible there. It serves as the framework paper of the strand SAMEN-PROV0001 and refers, for the individual questions, to the three specialist papers and the three tools of the package.

The central observation: conservation is far advanced in quantitative terms and fragile in implementation. Worldwide, some 5.9 million accessions are held ex situ, but at the end of 2022 only about 41 per cent of them were safety-duplicated, and around a quarter are awaiting regeneration. The collection is growing faster than the capacity to keep it alive.

1. The object

A seed is an organism in abeyance. It contains an embryo, a food reserve and a coat, and it has the property decisive for conservation of being able to reduce its metabolism to a level that lasts for decades or centuries. This property is not universal. Conservation biology distinguishes three behaviour types:

Orthodox seed tolerates drying to a few per cent moisture and storage below freezing point. Cereals, legumes and most vegetable species belong to this group. Only this type can be conserved by freezing in the literal sense, and only for it does the calculation apply that is treated in the *Seed Longevity* tool and in specialist paper P02.

Recalcitrant seed dies on drying. Oak, chestnut, cacao, mango, many tropical tree species. For these there is no seed bank in the usual sense, only field collections, in vitro cultures or cryopreservation of embryos and meristems — all more expensive, more dependent on personnel and more vulnerable than a cold store.

Intermediate seed lies between the two: drying yes, freezing no, or only to a limited extent. Coffee and citrus are examples.

This threefold division determines which part of diversity can enter a seed bank at all. It is the first reason why ex situ and in situ are not alternatives but must complement each other.

2. The quantitative situation

Of around 6000 plant species cultivated for agriculture, nine species account for more than 60 per cent of world plant production. This narrowing is the reason why diversity became a topic at all: what disappears from the field disappears from availability, and what disappears from availability is no longer available at the next disease or

climatic shift.

The Third Report on the State of the World's Plant Genetic Resources, based on data from 128 countries, four regional and thirteen international research centres and contributions from more than 1600 experts, gives the following figures for the reporting period:

Figure	Value
Accessions conserved ex situ worldwide	some 5.9 million (data as of 2022)
Of these, safety-duplicated	about 41 per cent (end of 2022)
Accessions in need of regeneration	24 per cent (page reference in the full text to be added)
Area under landraces and farmers' varieties	around 35 million hectares in 51 countries (reported sites in areas of high diversity, 2011–2022; not a global total)
Species reported as threatened in surveys	about 42 per cent

Set against this is the safeguarding level. Following the seventieth deposit on 17 June 2026, the Svalbard Global Seed Vault held a total of 1,401,285 samples from 134 depositing institutions and 6539 species, with a capacity of 4.5 million samples. The vault itself does not distribute seed; ownership remains with the depositing institutions. Only the depositing institution can withdraw material, as a rule when its own collection has been lost.

In Austria, the AGES genebank in Linz holds, according to its own status of 7 January 2026, a total of 4890 samples from 164 crop species, plus 880 medicinal and aromatic plants and 163 samples of threatened species from 458 species in total. The institution has existed since 1968 and, according to an undated APA Science report, also serves as a safety store for holdings of others, among them a bean collection from Aleppo. Alongside it stands the seed archive of the ARCHE NOAH association, one of the largest private crop plant collections in Europe. The Collection Atlas of the package presents these levels side by side and shows, for each figure, its status date and the state of the evidence.

3. Four layers and their frictions

3.1 Biological layer

Longevity in storage is not a property of the seed alone but a function of seed moisture content, temperature and species. The improved seed viability equation of Ellis and Roberts describes this relationship quantitatively and makes it possible to derive a half-life and a monitoring interval from a few parameters. The FAO genebank standards tie their requirements to it: minus 18 degrees in the base collection, initial germination above 85 per cent, regeneration when 85 per cent of the initial value is not reached, monitoring interval as one third of the predicted time to this threshold.

The friction lies in the fact that the equation is least well supported precisely at the standard condition. Its experimentally verified range begins at minus 13 degrees; minus 18 degrees is an extrapolation. Specialist paper P02 treats this limit in detail.

3.2 Legal layer

Seed is regulated in several ways, and the bodies of rules pursue different purposes. The Convention on Biological Diversity places genetic resources under state sovereignty. The International Treaty on Plant Genetic Resources creates, for the species of its Annex I, facilitated access in exchange for a standard material transfer agreement and enshrines farmers' rights in Article 9. The Nagoya Protocol governs access and benefit sharing and is implemented in the Union through a due diligence obligation on users. Market law, most recently the new Regulation on plant reproductive material, determines what may be placed on the market at all. Plant variety rights give the breeder an exclusive right.

The friction: conservation requires transfer, market law restricts transfer. The balance is struck through exemptions — conservation varieties, supply to non-professionals, exchange within conservation networks, experimental purposes. How far these exemptions reach was the main dispute of the trilogue negotiations, which ended in an agreement on 15 June 2026. Specialist paper P03 sets out the situation; the *Seed Law Check* tool works through the questions.

3.3 Data layer

A sample without passport data is a sack of seeds. Only the accession number, institute code, genus, species, origin and collecting site turn it into a resource that is findable and reusable. The standards for this are settled: the Multi-Crop Passport Descriptors as the description format, the FAO institute codes as the key, Genesys and EURISCO as aggregating catalogues.

The friction: documentation lags behind the holdings. According to the Crop Trust annual report 2025, Genesys lists over 4.46 million samples from over 500 collections, about three quarters of global ex situ holdings. Around a quarter exists but cannot be found through Genesys. The Third Report explicitly names inadequate documentation as a bottleneck for research and breeding. Specialist paper P04 treats the data layers.

3.4 Cultural layer

Knowledge of traditional seed cultivation and production has been inscribed in Austria's inventory of intangible cultural heritage since 2014. That is more than an honour: it states that conserving a variety is not only the safekeeping of its genetic material but the passing on of the knowledge of how to grow, select and propagate it. A variety whose cultivation knowledge has been lost is conserved as a data record and has disappeared as a crop plant.

The friction: ex situ conservation preserves genetic information at a point in time. On-farm conservation lets the variety continue to adapt, but thereby also changes it. Both paths are necessary, and they produce different objects.

4. The open fault lines

The implementation backlog. The collection grows, regeneration does not keep pace. A quarter of the reported accessions are awaiting propagation; cross-pollinators and crop wild relatives are particularly difficult here, because they require isolation areas and specialist staff. An accession that waits too long for regeneration is still in the catalogue but no longer viable.

Benefit sharing. The eleventh session of the Governing Body of the International Treaty in Lima in November 2025 produced, after twelve years of negotiation and fourteen working group sessions, no consensus on the enhancement of the Multilateral System. The point of contention remained monetary benefit sharing for the use

of digital sequence information. This is not a marginal question: if the use of genetic resources shifts from physical material to sequence data, a benefit-sharing system tied to material runs empty. The Cali Fund created under the Convention on Biological Diversity is intended to close this gap, but up to 2026 its resource mobilisation remained far below expectations.

The crop wild relatives. The closest relatives of crop plants carry traits that are absent in cultivated varieties and are under-represented in the collections. Their collecting often fails for lack of specialist staff for the respective groups; their regeneration is difficult because they germinate unevenly and are not bred for harvesting.

The quality of what is stored. The example of the Bavarian wild plant genebank shows what can lie behind a holdings figure: in 21 per cent of the accessions examined, more than half of the seeds were empty, pest-infested or dead; in ten per cent, more than three quarters. An accession count says nothing in itself about the diversity conserved.

5. Positioning of the strand

The strand SAMEN-PROV0001 treats the subject in four papers and three tools. It does not carry out field trials of its own but orders existing sources, makes the calculation paths traceable and presents the data in a form that can be verified. Every figure in the data layers carries a date, a source and an indication of whether it has been checked against the source. Figures without evidence are identified as such, not omitted and not estimated.

Figures

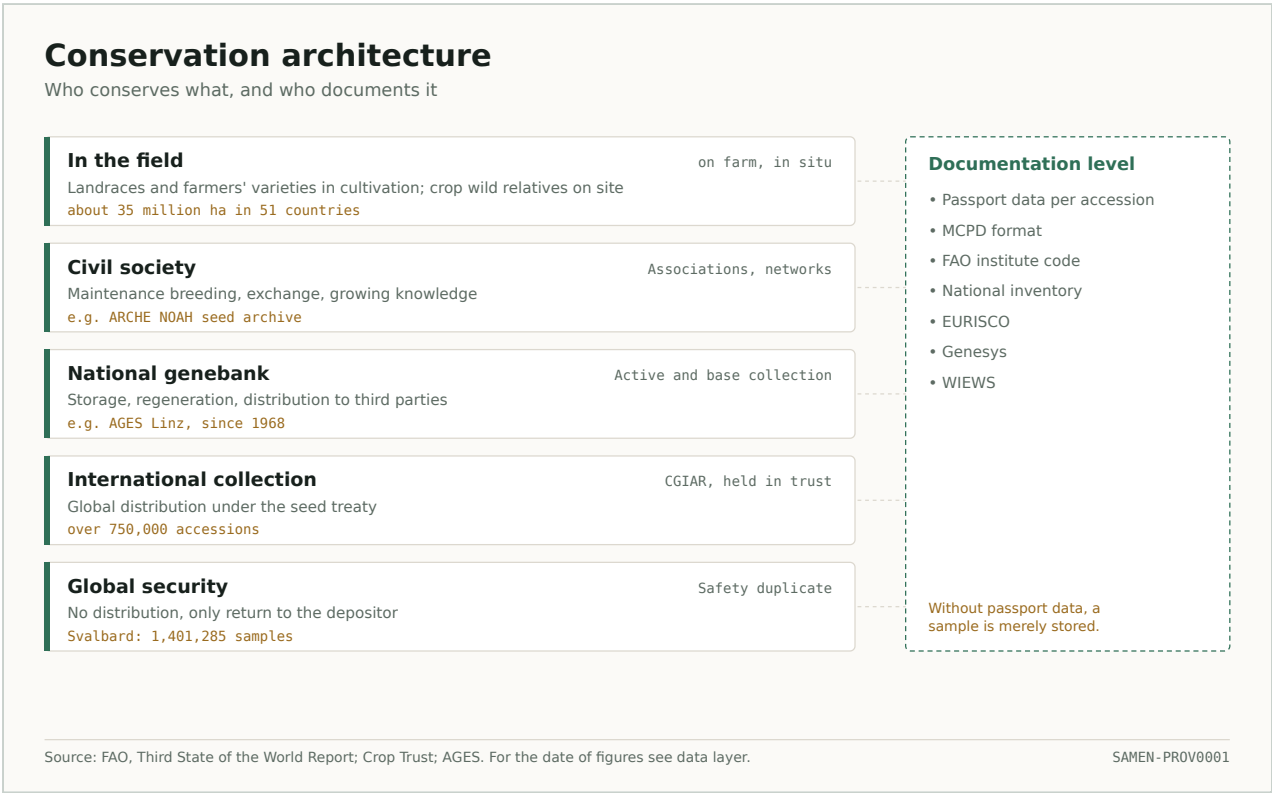


Figure 1. Conservation architecture of plant genetic diversity. Source: data layer of the strand, see figure footer.

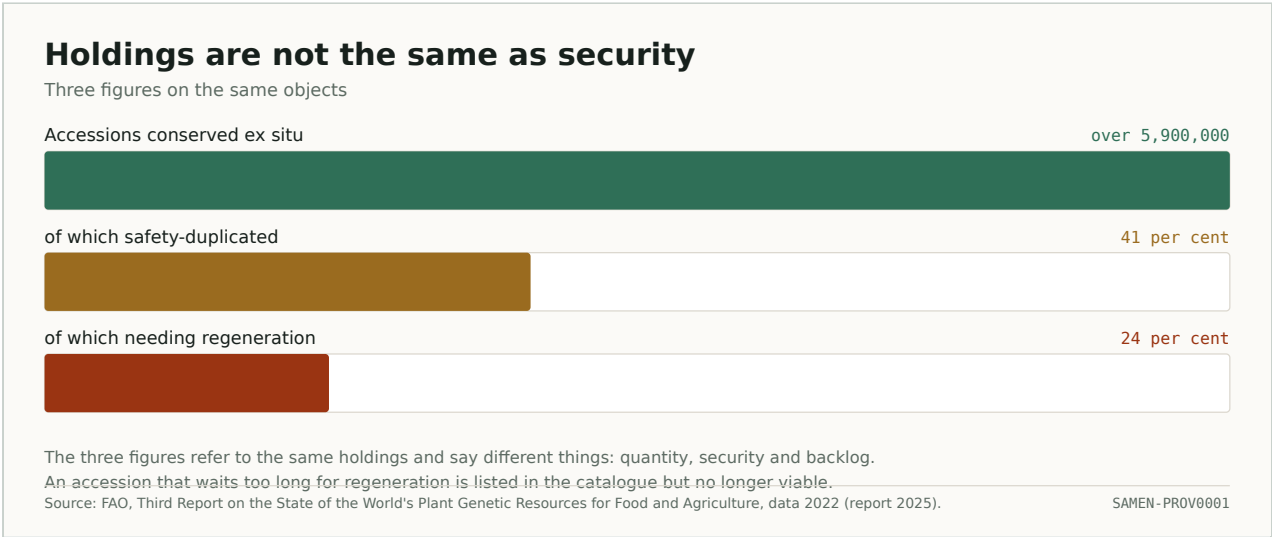


Figure 2. The global ex situ holdings and their subsets. Source: data layer of the strand, see figure footer.

Limits of this paper

The paper draws on publicly accessible reports and primary sources, not on surveys of its own. The figures for IPK Gatersleben, the Millennium Seed Bank and the ARCHE NOAH seed archive were checked against their sources in version 1.0; the Millennium Seed Bank collection count is dated 1 March 2023 because no more

recent total of collections was available. The global indicators rest on data up to 2022 compiled in the FAO report of 2025; the share in need of regeneration (24 per cent) is taken from reporting on the report and remains to be referenced with a page number in the full text. Version 1.3 corrects, following an independent review, among other things the Genesys share, the year of inscription in the heritage inventory and the characterisation of the on-farm area. The legal part reflects the situation before formal adoption of the plant reproductive material regulation; it is to be updated once the Official Journal text is available. The statements on cryopreservation and on recalcitrant species are contextual and do not replace the specialist literature on the procedure.

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