

Risks, consequences and early warning in the conservation of plant genetic diversity

Identifier	SAMEN-PROV0001-P06
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Version and date	3.0 · 2026-09-28
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Abstract

The loss of plant genetic diversity rarely occurs as an event. It occurs as a condition: an accession is listed in the catalogue and no longer germinates, a variety still has seed but no cultivation knowledge, a holding exists and cannot be found. This paper brings together fourteen risks in seven fields, rates them by likelihood and impact, describes the early warning signs for each and traces three chains of consequences through which a single circumstance leads to final loss.

The most serious finding: the two highest-rated risks — the regeneration backlog and the gap in safety duplication — are not hazards but permanent conditions. They have already materialised and are in effect.

1. Why a risk assessment is needed

Conservation is measured by holdings, and holdings grow. Some 5.9 million accessions are held ex situ worldwide, and in June 2026 the Svalbard Seed Vault passed the mark of 1.4 million samples. These figures suggest a security they do not cover: 41 per cent of the holdings are safety-duplicated, 24 per cent await regeneration, and a holdings figure says nothing about viability.

A risk assessment shifts attention from what exists to what can fail, and above all to the question of how a failure can be noticed before it becomes final.

2. The assessment

Fourteen risks, rated by likelihood (1 to 5) and impact (1 to 5). The score is the product; from 16 a risk counts as critical, from 9 as high, from 5 as medium. The ratings are reasoned assessments, not measurements; in the data layer each risk carries its justification and, where available, a documented incident.

No.	Risk	Field	Likelihood	Impact	Score	Rating
R-06	Gap in safety duplication	Operations	5	5	25	critical
R-01	Regeneration backlog	Operations	5	4	20	critical
R-05	Concentration in the seed market	Market	5	4	20	critical
R-02	War and armed conflict	Physical	4	5	20	critical
R-12	Recalcitrant species without a conservation route	Physical	5	4	20	critical
R-04	Missing long-term funding	Funding	4	4	16	critical

No.	Risk	Field	Likelihood	Impact	Score	Rating
R-09	Loss of cultivation knowledge	Knowledge	4	4	16	critical
R-03	Technical failure and climate effects	Physical	3	4	12	high
R-07	Benefit sharing runs empty	Law	4	3	12	high
R-10	Holdings without a record	Data	4	3	12	high
R-11	Apparent holdings from dead samples	Operations	3	4	12	high
R-13	Missing expertise for crop wild relatives	Knowledge	4	3	12	high
R-14	Voluntary work without succession	Funding	4	3	12	high
R-08	Market law cuts off conservation	Law	3	3	9	high

The distribution is notable: no risk lies in the lower range. This is not an artefact of the rating but the result of the selection — included were risks for which there is either a documented incident or a documented finding on the state of affairs.

3. What has already materialised

Five of the fourteen risks carry likelihood level 5, that is, "permanent condition, already in effect".

The duplication gap. 41 per cent of the world's ex situ holdings are safety-duplicated. The remaining 59 per cent exist only once. Any incident at one of those sites is therefore not damage but final loss.

The regeneration backlog. 24 per cent of reported accessions await multiplication. Out-crossing species and crop wild relatives are particularly affected, because they require isolation areas and specialist staff. An accession that waits too long remains in the catalogue and is no longer viable — the catalogue then records a holding that no longer exists.

Market concentration. According to GRAIN's analysis, in 2023 the four largest companies accounted for 56 per cent of the commercial seed market: Bayer 23 per cent, Corteva 19 per cent, Syngenta 10 per cent and BASF 4 per cent, in a total market of around USD 50 billion. The consequence is not only pricing power but a narrowing of breeding goals: what is bred is what sells in volume, and that is not the locally adapted variety.

Recalcitrant species. Desiccation-sensitive species — oak, chestnut, cocoa, mango, many tropical tree species — cannot be frozen. For them there is no seed bank in the usual sense, only field collections, in vitro cultures or cryopreservation. All three routes are more expensive, more staff-dependent and more fragile than a cold room, and a field collection carries the full site risk.

Loss of knowledge. A variety consists of its genetic makeup and of the knowledge of how to grow, select and multiply it. The second is not in storage. That traditional seed growing is listed as intangible cultural heritage in Austria names the fact and does not secure it.

4. What has materialised on record

Three incidents show what the abstract risk rating means in practice.

Aleppo. ICARDA's collection was held in Aleppo. After the escalation of the conflict from 2012, the institution could no longer operate its genebank there from 2015. In three steps — September 2015, 2017 and August 2019 — all 116,484 samples that ICARDA had deposited in the Seed Vault between 2008 and 2014 were withdrawn,

and the collection was rebuilt in Terbol (Lebanon) and Rabat (Morocco). Since 2017, ICARDA has re-deposited 42,729 accessions from multiplication in the Vault. The case proves that the safety layer works — and at the same time proves that it is needed.

Kharkiv. According to FAO and the United Nations (April 2023), Ukraine's genebank held more than 150,000 samples from 544 crops and 1,802 plant species, including 39,000 samples of Ukrainian origin. In May 2022, shelling damaged infrastructure, equipment and working collections at the associated field research stations. FAO and the EU relocated the collection more than 1,000 kilometres westwards by April 2023. Previously only 2,700 accessions had been deposited in the Seed Vault — less than two per cent of the holding.

Svalbard. Even the last line of defence is not a constant of nature. In October 2016, after heavy rain and unusually high temperatures, water entered the access tunnel of the Seed Vault; the incident became known in May 2017. The stored material remained undamaged, and the tunnel was renewed to be watertight by 2019.

5. Three chains of consequences

Risks rarely act alone. They act through chains in which each step is inconspicuous on its own.

From narrowing to vulnerability. Nine crops account for more than 60 per cent of global crop production → within those crops a few varieties displace the rest → the genetic base of the food supply narrows → a new pathogen or a climate shift hits a wide area at once → the answer would have to come from the diversity given up earlier.

From funding shortfall to silent loss. Core operations depend on time-limited funds → regeneration is postponed because it is the least visible task → accessions fall below the regeneration threshold → the catalogue stays unchanged, the holding does not → the loss is noticed at the next request, and by then it is final.

The Crop Trust puts the requirement for its endowment at USD 850 million, to generate some USD 34 million a year for the international collections; it estimates the cost of conserving a single variety in perpetuity at about USD 725. Project funding runs in cycles; the collection does not.

From benefit sharing to access restriction. Use shifts from material to sequence data → benefit sharing tied to material runs empty → countries of origin see no return for making material available → access rules tighten, negotiations end without result → the common pool everyone depends on shrinks.

The eleventh session of the Governing Body of the International Treaty in Lima (24 to 29 November 2025) reached no consensus on enhancing the Multilateral System after twelve years of negotiation and fourteen working group meetings; the point of dispute was monetary benefit sharing from digital sequence information. Contributions to the Cali Fund established under the Convention on Biological Diversity remained far below expectations up to 2026.

6. Early warning

The practical yield of a risk assessment lies not in the rating but in the signs by which a risk announces itself. Six of them can be observed without special equipment and should be recorded in every conservation operation:

1. **Monitoring intervals are exceeded** without germination tests being made up.
2. **The number of accessions multiplied each year falls** while the holding stays the same.
3. **Newly received accessions are not duplicated promptly**, or the duplicate is in the same building.
4. **Requests cannot be served** because the remaining quantity is lacking.

5. **Return flow from the multiplication network falls** or fails to arrive from individual growers.
6. **Holdings reports contain only one figure.** Where the number of accessions, viable holdings and duplicated holdings are not shown separately, the actual state cannot be seen.

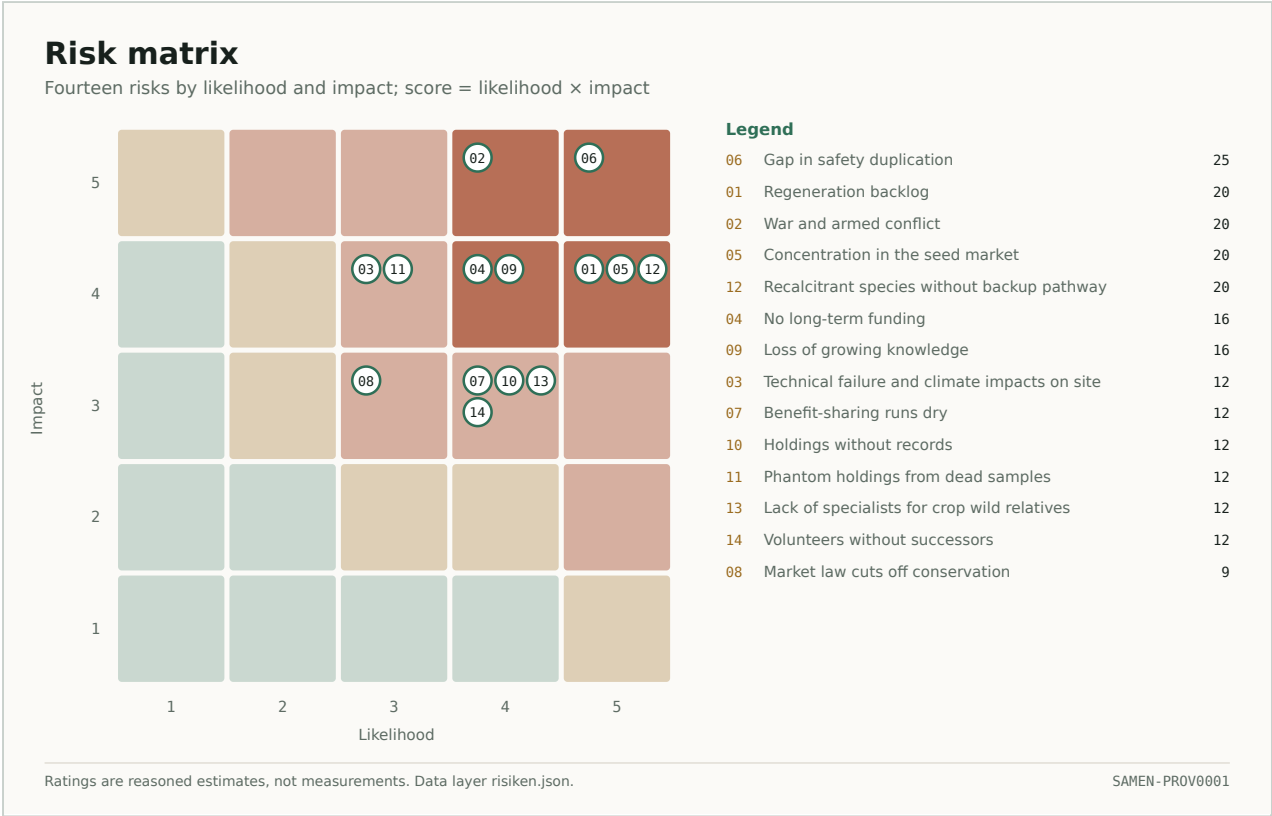
The sixth sign is the most revealing because it can be observed at no cost: a report that names only the number of accessions conceals the two figures that matter.

7. What follows

For a conservation operation, the countermeasures can be put in five sentences:

1. Duplication is a step of intake, not a later task.
2. Monitoring intervals come from the calculation, not from intuition, and are entered in the storage register.
3. Three figures are kept separately: accessions, viable, duplicated.
4. Each accession has two mutually independent growers.
5. Passport data are secured separately from the material, so that the holding remains reconstructable even if the material is lost.

Figures



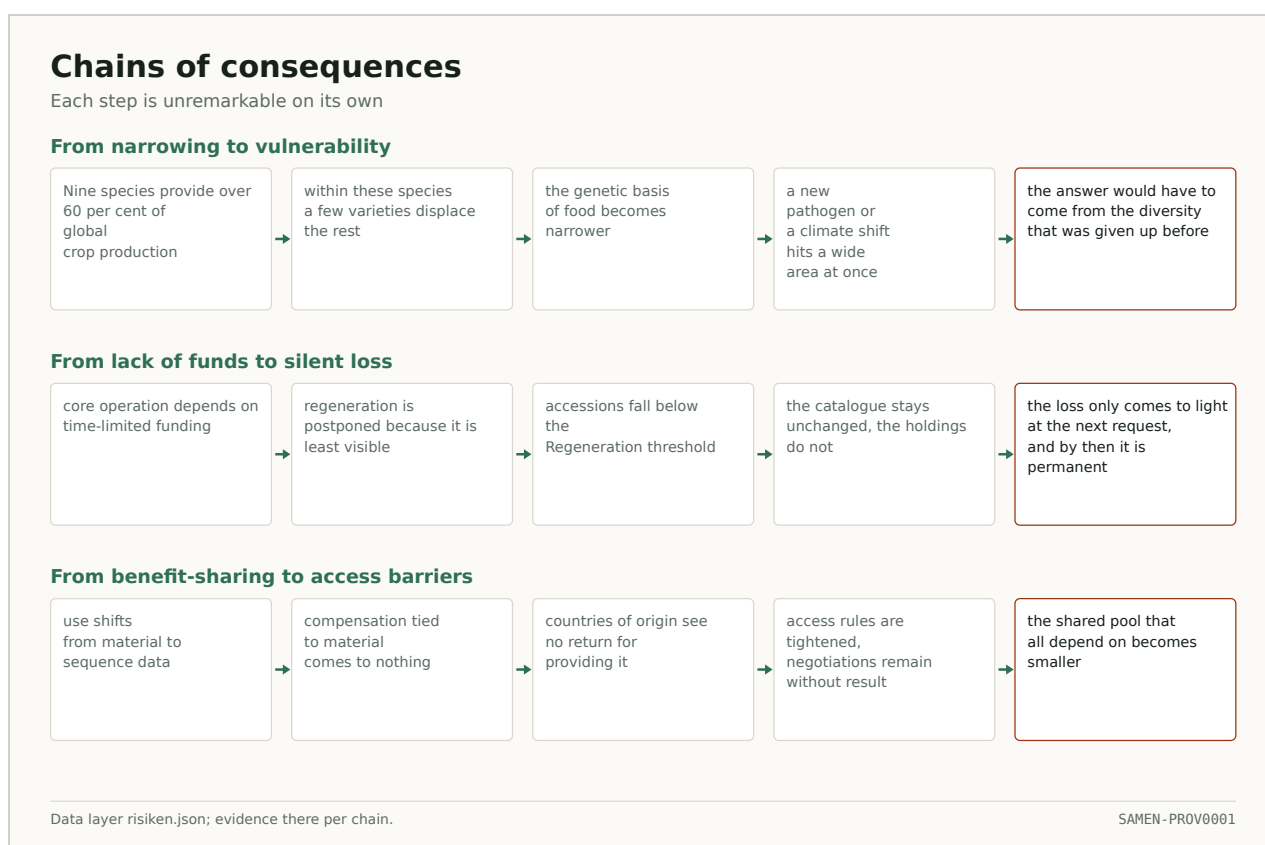


Figure 2. Chains of consequences. Source: data layer of the strand, see figure footer.

Limits of this paper

The ratings by likelihood and impact are reasoned assessments by the author, not measurements and not the result of an expert procedure; a rating by several independent specialists would be the next step and would make the ratings more robust. Two risks (R-12 recalcitrant species, R-14 voluntary work without succession) are included without a documented individual incident and are marked in the data layer as classified rather than documented. The market concentration figures refer to 2023 and come from a civil society analysis, not from official statistics. The incident at the Seed Vault is documented by the operator itself; version 1.2 corrects the year (October 2016 instead of 2017).

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