Weitzman's "Noah's Ark Problem": how to identify agrobiodiversity conservation priorities?

What is the Weitzman approach?

The Weitzman approach arises from a question related to the process by which it is possible to decide "which species to take on board Noah's Ark?". The suggestion was that Noah should take species on board "in the order of their gains in utility plus diversity, weighted by the increase in their probability of survival, per dollar of cost" [1] [2].

The Weitzman approach thus combines measures of diversity, current risk status and conservation costs so as to permit the identification of a cost-effective diversity-maximizing set of species/varieties or breed conservation priorities. Hence, for any given quantity of conservation funding available, it is possible to identify a priority conservation portfolio that maximizes the diversity that can be conserved.

What aspects of its implementation can be considered particularly interesting?

Weitzman's diversity concept has a strong appeal due to its rigorous mathematical justification and the possibility to derive optimum conservation decisions with well-defined properties.

The Weitzman approach shows that, under certain circumstances, a strong economic argument can be made for ensuring the conservation of species/varieties or breeds that are not currently threatened. This is because where the resource in question is particularly unique (i.e. contributes significantly to overall diversity), it is important to ensure that the resource will continue to exist far into the future even if its current risk status is low.

The Weitzman approach is also sensitive to the scale (national, regional or global) of analysis due to the existence of transboundary breeds. This is because national level analyses may identify small populations seemingly at risk as a priority for conservation even though there may be a secure and large population just across the border.

The Weitzman approach could be applied to account for dynamic change (such as climate change), with species/varieties or breeds that have been identified as part of the priority conservation portfolio being reassessed at regular intervals as a result of changes in risk status and the opportunity costs of conservation.

What data is required and how can we get this data (sources and methods)?

The Weitzman approach is made up of 3 separate indices. These include a diversity measure, a risk status measure and an economic measure. The data needed to identify a priority conservation portfolio is directly related to that required for the construction of each of the 3 indices.

Diversity index

Weitzman[3] argued that "the major unresolved conceptual problem would appear to be about defining an operationally meaningful value of diversity function. If diversity cannot be measured, it is difficult to comprehend how rational decisions are supposed to be made about how best to preserve it." Weitzman went on to assume that the loss of biodiversity due to the extinction of a species is exactly equivalent to the distinctiveness of that species (Weitzman's criterion). This means that the uniqueness of each species depends on the genetic distance between itself and its nearest relative, with diversity being a measure of distinctiveness or dissimilarity[4].

In applying the Weitzman approach to animal genetic resource issues, it has been noted[5] that diversity can be derived from different types of raw data, which can be a genetic distance matrix[6], or a set of weighted or unweighted characteristics, features or attributes[7], which may or may not reflect purely genetic properties of the considered unit. If for example, the degree of adaptation of a species/breed to a certain environment is used as a feature to assess diversity, this feature is certainly not completely genetically determined.

Other studies have based conservation priorities on the 'distinctiveness' of the operational taxonomic units (OTUs) in question[8], expected diversity[9], the contribution to actual diversity[10] or to a 'core set'[11], or just the degree of endangerment derived from simple quantities like actual or effective population sizes.

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Technical Note 1

The data for constructing a diversity index is often already available from previous genetic analyses. Where sufficient data exists, it has been shown that is also worthwhile incorporating within-population information into the diversity index.[12]

Risk status index

The risk status (or degree of endangerment) of a species/variety or breed is a measure of the likelihood that, under current circumstances and expectations, the OTU will become extinct within a specified period of time. Both demographic and genetic aspects of population decline are usually considered.[13] Dependencies (e.g. concurrence or synergistic relations) between OTUs can be accounted for by assuming that joint extinction probabilities differ from the product of the extinction probabilities of the interacting OTUs.[14]

For animal genetic resources (AnGR), the FAO categorises breeds as to their risk status on the basis of, *inter alia*, the actual numbers of male and/or female breeding individuals and the percentage of pure-bred females. Seven categories of risk status have been established. These are: "extinct, critical, endangered, critical-maintained, endangered-maintained, not at risk and unknown." A breed is "not at risk" if "the total number of breeding females and males are greater than 1,000 and 20, respectively; or if the population size approaches 1,000 and the percentage of females being bred pure is close to 100% and the overall population size is increasing".[15] The level at which a "not at risk" population is defined should in any case be sufficiently large to allow for genetic resource diversity to be maintained and for the animal population to be rebuilt at a future date, if so desired.

In addition to this definition of risk status based largely on population size and trends, a number of additional criteria have also been proposed. For example, although continuing to give more weight to population size and trends, the following factors have also been considered[16]: geographical distribution; evidence of indiscriminate crossing; the presence of breeding infrastructure, breeder's organisation or conservation scheme; socio-cultural importance; the existence of especially important traits; the reliability of the information available; and the political situation in the country where the breed is located.

For crop genetic resources (CGR), there does not yet appear to be a similar risk categorization and cut-off point. Some measure of the seed system function would be useful in any such index development.

The data for constructing a risk index can often be obtained relatively easily through the use of an expert focus group and existing secondary data regarding populations.

Conservation cost

The low effective population size of many existing species/varieties or breeds means that active intervention may be required in order to reduce risk status. Such interventions could involve *in-situ* and/or *ex-situ* breeding schemes, support for the rotation of breeding stock or seed exchange between villages, technical assistance and the administration of support payments[17]. The resources required for such interventions need to be estimated, along with an understanding of net production benefits and any opportunity costs incurred by forgoing the use of a different species/variety or breed. "Least cost" approaches can minimise opportunity costs by focusing conservation interventions on communities where *de facto* conservation is already taking place.

Revealed preference techniques (e.g. based on market data and farm modeling) can be used to estimate such production costs and benefits, as well as conservation intervention costs. However, the existence of important non-market values (e.g. related to adaptive traits, socio-cultural functions, etc.) means that stated preference methods (e.g. contingent valuation and choice experiments) may also need to be used. Through their ability to identify trait values and farmer preferences, they can be used, *inter alia*, to determine the payment levels necessary to motivate conservation through use. A number of examples of such stated preference work for AnGR exist for Mexico and in East Africa.[18]

The data for constructing the conservation cost index does often need to be obtained through primary data collection but can be obtained relatively cheaply.

What needs to be done to implement the Weitzman approach

Despite the conceptual basis having been developed for an important decision-support tool, there is no existing example of this approach having been used to inform actual "real-life" conservation policy design and implementation. This is true for both AnGR and CGR.

This is despite the fact that rural appraisal methods, in conjunction with genetic resource economics analytical techniques, have been shown to be capable of providing the data required for understanding the type and costs of the interventions necessary to promote the conservation and sustainable use of agrobiodiverse resources.

The challenge is now for such multidisciplinary multi-methodology approaches to be applied more widely to the issue of agrobiodiversity conservation and sustainable use, especially within the context of on-going conservation policy design and implementation. The application of the Weitzman approach can be considered to directly contribute to the Convention on Biological Diversity's COP 8 Decision VIII/25 (Incentive measures: application of tools for valuation of biodiversity and biodiversity resources and functions).

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