Methodologies for *in situ* conservation of crop wild relatives

What are crop wild relatives (CWR)?

CWR – are species relatively closely related to crops (or any socio-economically valuable species), which may be crop progenitors and to which the CWR may contribute beneficial traits, such as pest or disease resistance, yield improvement or stability.

Why are CWR's important?

N.I.Vavilov recognized the potential of CWRs for crop improvement in the 1920s and 1930s and included them in his plant genetic resource (PGR) collecting programs (Loskutov 1999, pp. 55–81). CWR are important for:

- Agricultural researchers began using CWRs in the 1940s and 1950s to improve major crops
- (Plucknett et al. 1987; Hodgkin et al. 1992).
- By the 1960s and 1970s, breeding successes involving CWRs had accelerated (Harlan 1976, 1984; Hawkes 1977; Prescott-Allen and Prescott-Allen 1981; Hoyt 1988), especially using species within the primary gene pools of crops (Harlan and de Wet 1971).
- It also became recognized that CWRs were instrumental in the productivity and stability of traditional agro-ecosystems through natural genetic exchange between landraces and their wild, weedy relatives (Harlan 1965).
- By the 1980s and 1990s application of genetic engineering to crop improvement allowed genes from distantly related and even non-related taxa to be incorporated into crops, thereby broadening the value of CWRs by expanding their usefulness into secondary and tertiary crop gene pools.

Why in situ conservation of CWR's?

Perhaps because *ex situ* conservation developed as the preferred approach to safeguarding crop genetic resources during the 1970s and 1980s when *in situ* conservation of landraces in particular was thought to be impractical, the agricultural community did not begin to embrace *in situ* CWR conservation until the 1990s, despite the fact that influential crop scientists like Frankel (1970) and Jain (1975) had called for its use earlier.

Contributing to this shift was an appreciation that *ex situ* conservation was not succeeding as expected in safeguarding acceptable levels of CWR diversity (Hoyt 1988, p. 26; Davies 1991, pp. 64–65; FAO 1996a).

Foremost among the reasons for this are the difficulties and often high costs of capturing, preserving and utilizing genetic variation in CWRs that possess one or more of the following characteristics: dispersed, sometimes small, genetically distinct populations with poorly known genomes, low seed production and/ or viability, high maintenance demands of clonal collections, problems in regenerating stored material, and seed recalcitrancy, this latter trait sometimes making conventional storage impractical (Berjak and Pammenter 1997).

Natural genetic introgression between crops and their CWRs also stimulated interest in *in situ* conservation (Harlan 1992), as did the nearly cost-free value of the evolutionary processes that generate diversity and much of the breeding value of CWRs.

In weighing these points along with what was known about seed viability loss and genetic drift within *ex situ* collections (Hamilton 1994), one can see why *in situ* conservation has today joined *ex situ* conservation as a key element of the integrated tool kit most agricultural scientists feel is needed to conserve CWRs

In the minds of many people, *in situ* conservation is taken to mean the creation of protected areas and implies a narrow ecosystem approach, with the inclusion of local communities and conservation of species being incidental.

This concept is now rapidly changing, as more focus is placed on individual target species and the needs and well-being of local communities and people are beginning to receive more consideration.

It is also clear that *in situ* conservation cannot be the sole mode of conservation: it will not be possible to turn the location of every population of wild plants into a protected area, due to cost considerations or other land-use reasons.

In situ conservation will need to be complemented by *ex situ* conservation where appropriate and, in particular, some sites will need to be managed with local stakeholders in a participative manner.

The goal of PGR conservation is to maximize the proportion of the gene pool of the target taxon conserved, whether in situ or ex situ, which can then be made available for potential or actual utilization

In situ conservation would be the *conservation of components of biological diversity in their natural habitats*.

This general definition of the in situ strategy may then be implemented using three types of techniques:

- **protected areas**
- on-farm
- home garden

Protected area have: - targets areas → for wild species

- management → are managed by conservationist

Protected area is a area of land dedicated to the protection and maintenance of biological diversity, and of natural and associated cultural resources, and managed through legal or other effectives means

Currently within protected areas the objective is likely to be broad biodiversity conservation at the ecosystem or species diversity level which may involve the detailed monitoring of keystone or indicator species, but is unlikely to focus on intraspecific diversity within any single species.

As in the case of genetic conservation, the objective will be to maintain not only the appropriate effective population size, but also the level of genetic diversity within the target population.

Protected areas

As protected areas have not been established specifically to conserve the genetic diversity within CWR species, it is perhaps not surprising that none of the existing categories matches the definition of a genetic reserves outline above.

However, some of existing IUCN categories are amenable for management adaptation to the conservation of the genetic diversity of wild plant species and CWR.

- <u>Category I a</u>: strictly protected reserves (often small) set aside and left untouched to protect particular species under threat;
- <u>Category II</u>: large ecosystems scale protected areas maintained to allow CWR to continue to flourish and evolve under natural condition;
- <u>Category IV</u>: small reserves managed to maintain particular species, for example through controlled grazing or cutting to retain important grassland habitat, coppicing to maintain woodland ground flora or sometimes even intervening to restore habitats of threatened CWR species.

Types of protected area

A great diversity of different types of protected areas exists, depending on the conservation objectives, the degree of human activity permitted and the extent of involvement of stakeholders.

IUCN Protected Areas management categories

Category Ia: Strict nature reserve/wilderness protection area managed mainly for science or wilderness protection

Category Ib: Wilderness area: protected area managed mainly for wilderness protection

Category II: National park: protected area managed mainly for ecosystem protection and recreation

Category III: Natural monument: protected area managed mainly for conservation of specific natural features

Category IV: Habitat/species management area: protected area managed mainly for conservation through management intervention

Category V: Protected landscape/seascape: protected area managed mainly for landscape/seascape conservation or recreation

Category VI: Managed resource protected area: protected area managed mainly for the sustainable use of natural resources.

Within the context of in situ conservation of wild plant species genetic reserves conservation is the most appropriate conservation technique.

Genetic reserves: *the location, management and monitoring of genetic diversity in natural wild population within defined areas designated for active, long-term conservation* (Maxted et al.,1997)

- active conservation: site is managed even if that active management only involves regular monitoring of the target taxa.
- long-term conservation: because significant resources will have been invested in the site to establish the genetic reserves and it would not be cost effective to establish such a reserves in the short term.

This type of conservation is applicable for orthodox seeded and non orthodox seeded species, permits multiple taxon conservation in a single reserves and allows for continued evolution.

Genetic reserves may be established on private lands, roadsides, in indigenous reserves and community conserves areas as well as officially recognized protected areas; as such, it is important to note that they may equally well be established outside as inside protected areas.

But often the simples way forward in economic and political terms is for countries to locate genetic reserves in existing protected areas (e.g. national parks) as this is likely provide some benefit for local people and so is likely to grain their support.

Only realistic conservation option is *in situ* genetic reserves conservation with *ex situ* conservation acting as an essential back-up system to ensure complementary conservation for the most important taxa.

In situ conservation in genetic reserves is the only practical option for their genetic conservation simply because of the need to conserve the full range of intraspecific genetic diversity and sheer number of CWR that are involved.

But, many existing protected areas are not actively managed for biodiversity conservation, in fact, that is not possible to actively manage a site for all the biodiversity contained within it because of the competing management requirements of different species.

- Active management implies some form of dynamic intervention at the site, even if that intervention were simply limited to an agreement to monitor target populations included.
- Passive conservation involves less active intervention without management or monitoring of population, although there may be general ecosystem management, and all species are passively conserved if the entire ecosystem or habitat is stable and individual species could be eroded and are inherently more vulnerable for extiction.

Having made these points and accepting that no network of protected areas offer ideal protection for all biodiversity, if the goal is in situ conservation of plant genetic diversity.

The establishment of genetic reserves is most efficient within existing actively managed protected areas.

The reasons being:

- these sites already have an associated with private land or roadside where conservation value and sustainability are not a consideration
- it is relatively easy to amend the existing site management to facilitate genetic conservation of wild plant species
- it means creating novel conservation site can be avoided, thereby avoiding the possibility prohibitive cost of acquiring previously non-conservation-managed land.

A. Genetic reserves location and design

Genetic reserves location

1. Taxonomic information
2. Demographic information
3. Genetic variation
4. Ecological information
5. Policy and socio-economic information

Genetic reserve design

1. Optimal reserve design
2. Reserve size
3. Population size
4. Reserve shape
5. Political and economic factors

Genetic reserves location

The objectives of genetic reserve location is to determinate which areas or sites containing the target species are most important in terms of genetic diversity for creation of a genetic reserve or a network of genetic reserves.

The methodology used for identifying genetic reserves influence the scope and the cost of the exercise and will determinate whether the range of the genetic reserves is representative of the genetic diversity of the target species.

The most important prerequisite for the proper selection of genetic reserves locations is adequate knowledge of the target species and their habitat.

This knowledge will allow conservation planners to select the most optimum sites for inclusion in a genetic reserve network system.

The information required may be broadly divided into five categories:

1. **Taxonomic**
2. **Demographic**
3. **Genetic**
4. **Ecological**
5. **Policy and socio-economics.**

1. Taxonomic information

First of all, the identify of target taxon needs to be clearly established, as this will ultimately have consequences for the selection of reserves areas.

Intraspecific variation is of major importance in selecting sites for genetic reserves since it is often the basis for distinguishing subspecies, ecotypes or chemotypes.

Tolerance traits and resistance to a particular diseases are often traced to a small number of plants in a very specific region.

Proper taxonomic information as well as common names used by local communities should, therefore, be well documented.

The value of local names is that they allow comparison of target taxa between different sites and help ascertain whether one is dealing with the same or different entity.

Standard Floras (*Flora Europaea, Med-Checklist, Euro+Med PlantBase*) provides a reliable source of taxonomic information on plants which occur in a given country or region and should be fallowed, unless it is possible to determine the correct name (if different) through other sources.

2. Demographic information

Ecogeographic survey will identify broad areas where reserves could be established but they are unlikely to provide the best suites of specific locations representative of the diversity of the target taxon.

Demographic information is very relevant in reserves selection as it included:

- **the distribution range of the populations of the target taxon**

Passport data associated with herbarium specimens and gene bank accessions are often a first source of information for defining locations from where the accessions have been collected. Use this data with caution because it would provide only those areas where collections have been made and may not represent the entire distribution of the species.

- **numbers of populations and numbers of individuals within populations**

Number of populations across the distribution range should be determined and their characteristics studied and documented. This would include number of individuals in each population and in particular the number of mature individuals. This information is critical in determining effective population size.

- **age-class distribution**

The age-class distribution within and across populations can be useful indicators of the status and viability of the population. The ratio of the various age groups in a population determines the current reproductive status of the population and indicates what may be expected in the future.

3. Genetic variation

Knowledge of the amount and distribution of genetic diversity in target species is among the major criteria in locating sites for genetic reserves.

The main objectives for setting up a genetic reserves is to ensure that maximum genetic diversity of the target species gene pool is captured in the reserves system.

This diversity is essential for species to evolve in their changing environment and to ensure their long-term persistence and survival.

Genetic diversity occurs at various levels from the ecosystem, through its component species, population, family groups, landraces and genotypes to the molecular level.

In practice, it is unlikely that information on the amount and distribution of genetic variability will be available for most species, and studies to generate this information can be too costly and time consuming.

The following are the main proxy information that could be used to infer information on genetic variation and can help conservation planners in their task of capturing maximum genetic diversity for target species:

- **Ecogeographic representation** – it assumes a direct relationship between genetic diversity, and geographical location.
- **Genecological zonation** – it is based on the assumption that genetic variation follows some of the patterns of ecological variation (local distribution of ecosystems, climatic information, physiographic and geological maps and soil survey) and biological characteristics of the target species (their breeding system and level of endemicity, risk and threat of their populations and resources available).

- **Morphological characters** of existing material maintained in ex situ collections can play an important role in the analysis of variation in crop species and their relatives, largely vecause their collection does not require expensive technology.

The question of how many population are necessary to capture maximum genetic diversity is an important one, and on which there has been much debate.

Commonly cited recommendations include:

- Sampling from 5 population to effectively capture 90-95% common alleles (Brown and Briggs, 1991).
- Collecting 50 individuals from 50 populations (brown and Marshall, 1995)

Selecting population according to common ecological reserves guidelines did not capture more genetic diversity than selecting population at random.

The number of populations selected is much more important than how those populations were selected.

Thus, focusing on ecological features for selecting sites for conservation will ensure representation of genetic diversity only when sufficient number of populations are included in reserves.

4. Ecological information

Information on the target species environment is just as important as information on the target species itself to ensure the long-term persistence of the target species in its natural habitat.

The different types of information under this category would be very helpful in the selection of sites for conservation:

- **Ecosystem condition and function** – quality of ecosystem service and ecosystem resilience indicate the system's capacity to maintain component species and in particular target species.
- **Threats to the habitat** – important to identify not only threatens habitat condition, but also the degree and extent of threat, which would influence the decision to identify site for inclusion in the reserves system. Threats include: invasive species, overgrazing, insects pests and pathogens, pollution and climate change, etc.
- **Climate change** - this is significant threat to the maintenance of biological diversity and ecological systems. This threat have a significant influence on the distribution, abundance, phenology and physiology of a wide range of species, ecosystem composition, structure and dynamics. *Climate change have minimal impact in areas in mountainous zones* - establish protected areas here, may be a priority.
- **Habitat diversity** – sites with spatial or temporal heterogeneity should be given priority over homogeneous areas. The wider range of habitat diversity and juxtaposition of different habitats within a potential site, the better the reserve will be at conserving maximum diversity, both at intraspecific and interspesific levels. This will esure that the target species will preserve the variation genes and genetic combinations associated with ecotypic and taxonomic differentiation leading to more effective conservation of genetic diversity.

- **<u>Species distribution</u>** – the geographical distribution of target species can be predicted using GIS (Geographical Information System). Different parameters – climatic data (temperature and rainfall), soil data, are used to determine potential locations. Site identified using GIS method should always be validated in the field to assess the presence or absence of the target species and the state of the habitat.
- **<u>Species dispersal</u>** – the most common models of long distance dispersal for terrestrial plants are: wind, water, animals and humans.

  - *<u>wind dispersal</u>* the distance of transport can be estimate using information on the direction of predominant winds coupled with prevailing weather conditions.

  - *<u>water dispersal</u>* can also be predicted by direction and speed of flow

  - *<u>animal dispersal</u>* is less predictable depend the species of animal and the morphological characteristics of the seed

  - *<u>human transport</u>* seed in vehicles, often in topsoil and agricultural products – invasive species are often spread in this way.
- **<u>Phenotypic plasticity</u>** – the capacity of individual species to adapt to changing conditions may well be an important determinant of population persistence in the face of climate change. In selecting potential sites for genetic reserves the variability offered by phenotypic plasticity should be an important criterion particularly in the context of climate change.

5. Policy and socio-economic information

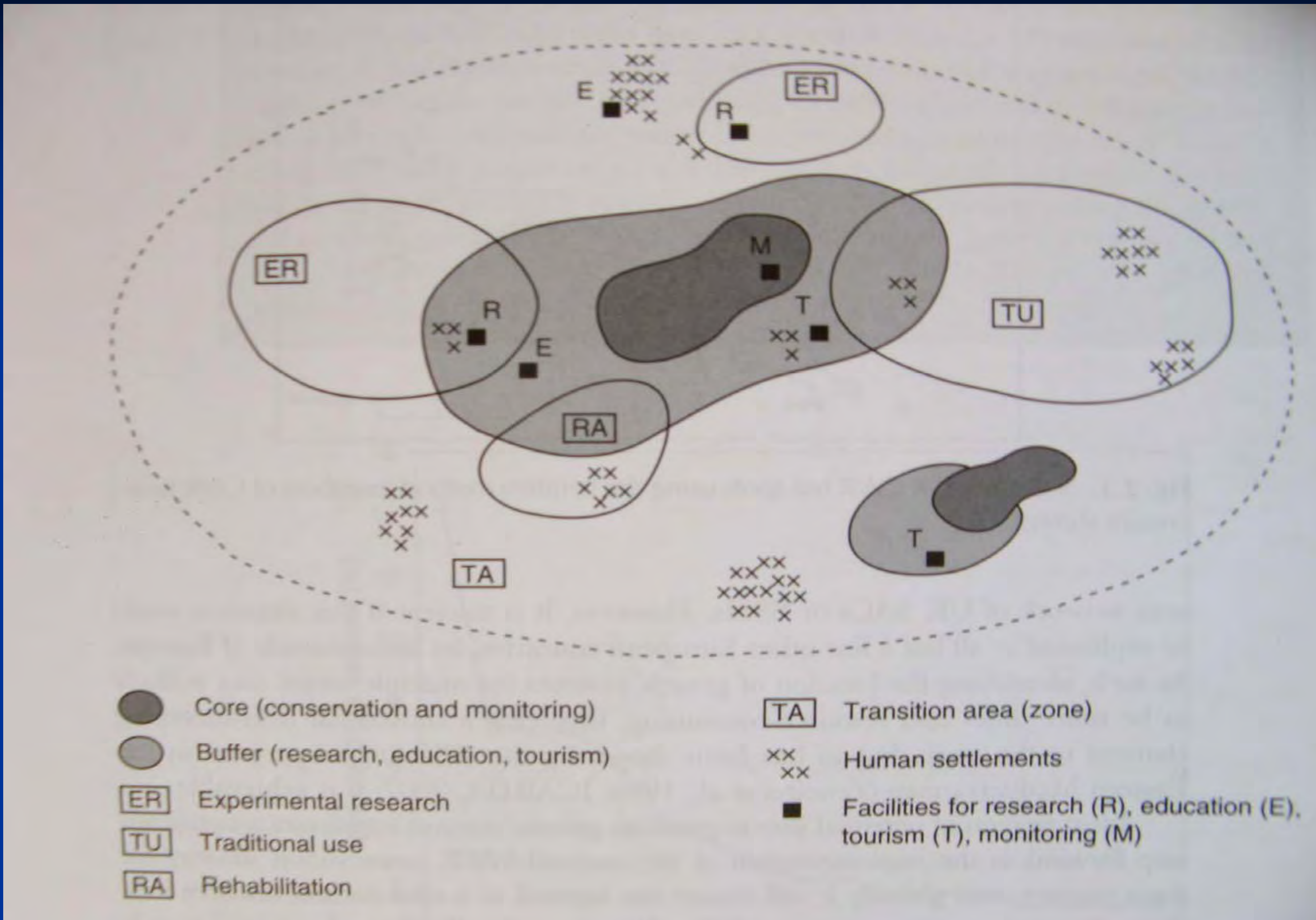
In addition to biological factors, policy, socio-economic and cultural factors of the target taxa should also be considered in locating potential genetic reserves sites.

It is recommended to carry out ethnobotanical surveys to document the use and level of harvesting of target species from natural habitats.

- **Legal status** – it is always useful to determine the historical land tenure of the potential sites and the current ownership status of the land. This will have major legal implications in the management of the site and in particular with regard to accessibility and land rights as in situ genetic conservation involves the permanent appropriation of the land and the management of the sites, thus raising a series of constraints ranging from economic to scientific and organizational matters.
- **Economic considerations** – the cost of reserves management is a critical factor in site selection. In general, the cost include land prices, management costs – which will vary according to the type of interventions required and opportunity costs.

Genetic reserve design

1. Optimal reserve design



- **the core** - typically a protected area such as a national park, is designed to provide for conservation of biotic diversity, with research being limited to monitoring activities
- **the buffer zone** – is a region in which research, tourism, educational activities and traditional subsistence activities of indigenous peoples are emphasized. Protects the core from edge effects and other factors, such as potential conflict with local communities, that might threaten the viability of the target populations in the core.
- **the transition zone** – its outer limit not rigidly defined, constitutes an area where major manipulative research, ecosystem restoration and application of research to management of exploited ecosystems are carried out.

This plan assumes that the core area will be large enough to accumulate a MVP of 1000-5000 potentially breeding individuals already growing as part of natural ecosystem.

2. Reserve size

In practice, the size of a reserve is often dictated by the relative human population density and the suitability of the land for human exploitation (agriculture, urbanization, logging).

The debate is often centred on the relative advantage of a single large versus several small reserves, the so-called SLOSS debate (Single Large Or Several Small).

The current consensus is that the optimal number and size of reserves will depend on the characteristics of the target species and their habitat requirements.

- <u>Large reserves</u> – are better able to maintain species and population diversity because of their greater species and populations numbers and internal range of habitats.
- <u>Small multiple reserves</u> may be more appropriate for annual species, which are naturally found in dense but restricted stands.

CWR are much more widely distributed therefore a number of reserves located in different segments of the distribution area of the target species, would be required to cover its ecogeographic divergences and to deal adequately with the genetic changes which occur over its geographic range.

The socially optimal number of reserves site (which maximizes social welfare) is generally larger than the ecologically optimal number (which maximizes an ecological objectives such as population viability).

However, when the opportunity costs of conservation can be offset by land transactions, the socially optimal number of reserves sites might be closer to the ecological optimum.

3. Population size

Minimum population size (MVP) – size for any given habitat as the smallest population having a 99% chance of remaining extant for 100 years.

MVP depend to:

- unpredictable factors - sever drought, appearance of a destructive new pest, hurricanes, etc)
- species from species - depending on the mode of reproduction and life form (annuals are more vulnerable to such changes compared to perennials species). Small annual populations (a few thousands of individuals) are even greater when this life form is coupled with self-pollination (majority of CWR).

In reserve design, a minimal population size should be regarded only as a last resort and it is recommended that a much larger population (up to 10,000 are desirable) should be considered for in situ genetic conservation as a safety target.

4. Reserve shape

Reserve shape is often the last of the concerns during reserve design as other factors tend to dictate the final shape a reserve takes.

The most optimal shape would be a round reserve where the edge to area ratio is kept at a minimum.

Fragmentation of the reserve by roads, fences pipelines, dams, agriculture, intensive forestry and other human activities will necessarily fragment and limit the effective reserve size, multiply the edge effects and way leave populations in each fragment unsustainable.

5. Political and economic factors

The reserve design should pragmatically be applied to allow complementary use as agricultural, industrial or recreational resources.

Reserve use – reserve design should take into account the needs of local communities, local farmers, landowners and other members of the local population who may depend on the proposed reserve site for their livelihood.

During the planning phase of the reserve, consultation should also be held with regional and national governments as well as with local communities, thus ensuring that establishment and management agreements are in place before the reserve is functional.

Reserve sustainability – Establishing and managing an in situ genetic reserve is resource expensive and therefore both reserve and target taxa must be sustainable over an extended period of time to make the investment worthwhile.

Reserve sustainability depends:

- on proprieties of target taxa,
- MVP size if is large, sustainability is higher
- reserve size if is large, sustainability is higher
- shape reserve
- management of the reserve
- genetic reserves are design as part of reserves network that include high-quality sites.

The genetic reserve system should be designed in a cost-effective and efficient manner and in most cases common sense will dictate that it will be preferable to conserve multiple target taxa in the same reserve.

B. Genetic reserve management

1. Genetic reserve management plans
2. Genetic reserve management plan content
3. Design and implementation of a genetic reserve management plan
4. Genetic management outside of protected areas

The in situ conservation of plant genetic diversity implies a high level of target population scrutiny, and the conservationist needs to be assured not only of relative demographic stability but also that, although the target population will continue to evolve, the magnitude of genetic diversity is not dramatically curtailed.

Protected areas are not the normal domain of CWR species, as many agricultural CWR species are more often associated with disturbed, pre climax communities at earlier stage of succession.

So although the preference is often to locate genetic reserves in existing protected areas, those protected areas must be actively managed.

Therefore, the reserves in which they are found is likely to be smaller, commonly abutting urban areas and will require active management intervention to maintain the habitats characteristics and prevent the site reaching its natural climax state.

Active management implies the need for associated target species and habitat monitoring, management and protection, and in turn these are often dependent on the existence of a management plan that constitutes the major tool to assist the conservationist in ensuring a viable target population that its inherent genetic diversity is maintained.

1. Genetic reserve management plans

The writing and implementation of a management plan for a genetic reserves is an essential step in efficient and effective in situ genetic conservation of CWR diversity.

The primary aim of genetic reserves management plan is to ensure the maintenance or enhancement of the genetic diversity of the target CWR taxa within the reserve.

Subordinate managements goals for the reserve site are met:

- Maintaining maximum genetic diversity of the target taxon and key associated species
- Promoting general biodiversity conservation and minimizing threat to all levels of diversity
- Maintaining natural ecological and evolutionary processes that are not deleterious to the target taxon gene pool
- Ensuring that appropriate, but minimally intrusive, management interventions enhance target taxon diversity
- Promoting public awareness of the need for genetic and protected area conservation
- Facilitating the linkage of conservation to sustainable usage by ensuring that diversity is made available for actual or potential utilization.

Is a fundamental difference between ecosystem-based protected area management and genetic reserve management that is reflected in the style and content of their respective management plans.

- **For ecosystem-based** protected area management the goal is commonly broader in terms of taxa (entire communities, ecosystems or vegetation types) and monitoring is focused on species - presence/absence or indicator population characteristics – density, frequency and cover with a goal of assessing overall biotic health of the site. The taxon focus is likely to be either keystone or threatened wild species.
- **For genetic reserve** management the focus is narrower in terms of taxa (relative smaller number of the taxa) and monitoring is based on estimating genetic diversity, as well as species – presence/absence or certain species population characteristics. The taxon focus is likely to be priority CWR taxa that have a socio-economic value associated with their actual or potential use as gene donors.

For CWR species we need for a management plan - is more critical than for traditional ecosystem-based conservation because potentially with maintenance of genetic diversity as a goal it would be possible for a CWR population to maintain normal population characteristics – density, frequency and cover while losing genetic diversity.

A management plan is also likely to be require because the location of genetic reserves will often result from a compromise between biological best practice and sociopolitical-ethnographic expediency.

This compromise in locating genetic reserves means that the management plan can act as a useful tool to balance competing priorities.

2. Genetic reserve management plan content

1. **Preamble**:
- Conservation objectives
- Site ownership and management responsibility
- Reasons for location of reserve
- Evaluation of populations of the target taxon
- Reserve sustainability
- Factors influencing management (legal constraints of tenure and access)

2. **Conservation context**:
- Likely interaction between target taxon and climate change at site
- Externalities (political consideration)
- Obligations to local people (allowing sustainable harvesting)
- Present conservation activities (ex situ, in situ)
- General threat of genetic erosion

3. **Site abiotic description**
- Location (longitude, latitude , altitude)
- Map coverage
- Photographs
- Detailed physical description (geology, geomorphology, climate and predicted climate change, hydrology, soils)

4. **Site biotic description:**

- General biotic description of the vegetation, flora and fauna of the site
- Focusing on the species that directly interact with the target taxa (keystone species, pollinators, seed dispersers, herbivores, symbionts, predators, diseases, etc)

5. **Site anthropogenic description**:

- Effects of local human population
- Land use and land tenure (and history of both)
- Cultural significance
- Public interest (educational and recreational potential)
- Bibliography and register of scientific research.

6. **General taxon description:**

- Taxonomy (classification, description, iconography, identification aids)
- Wider distribution
- Habitat preference
- Phenology
- Breeding system
- Means of reproduction (sexual and vegetative)
- Regeneration ecology
- Genotypic and phenotypic variation
- Local name(s)
- Users

7. **<u>Site specific taxon descriptors:</u>**

- Taxa included
- Distribution, abundance
- Demography
- Habitat preference
- Minimum viable population (MVP)
- Genetic structure and diversity of the target taxon within site
- Autecology (the relation of an organism to its environment)
- Specific threats to population(s) (potential for gene flow between CWR and domestication)

8. **<u>Site management policy</u>**:

- Site objectives
- Control of human intervention
- Allowable sustainable harvesting by local people and general genetic resources exploitation
- Educational use
- Application of material transfer agreements

9. **Taxon and site population research recommendation**

- Taxon and reserve description
- Autecology and synecology (the ecological interrelationships among communities of organisms)
- Genetic diversity analysis
- Breeding system, pollination
- Characterization and evaluation

10. **Prescription (management interventions):**

- Details (timing, frequency, duration, etc) of management interventions
- Population mapping
- Impact assessment of target taxon prescription on other taxa at the site
- Staffing requirements and buget
- Project register

11. **Monitoring and feedback (evaluation of interventions):**

- demographic, ecological and genetic monitoring plan (including methodologies and schedule)
- Monitoring data analysis and trend recognition
- Feedback loops resulting from management and monitoring of the site in the context of the site itself as well as the regional, national and international context.

3. Design and implementation of a genetic reserve management plan

Writing a formal management plan for the genetic reserve involve clarifying the conservation context, collecting available information and possibly researching the abiotic, biotic and anthropogenic characteristics of the site, describing the various target taxa and their populations present in the reserve site and on the basis of all this information , generating the management prescription which details the required management interventions.

The establishment of the genetic reserves will mean either the revision of an existing management plan or writing of a genetic reserves management plan where much of the details can be taken from the existing protected area management plan.

The first step in formulating the prescription (where you have a regime of minimum effective management interventions) will be to observe the various dynamics of the site.

It should be surveyed so that the species present in the ecosystem are know, the ecological interaction within reserve understood, a clear conservation goal decided and a means of implementation agreed.

It is important to involve the local community in reserve establishment and the drafting of the management plan.

Time should be taken to explain the reasons for the establishment of the reserve to the local community , seek their approval and when designing the reserve take into consideration their needs and aspiration.

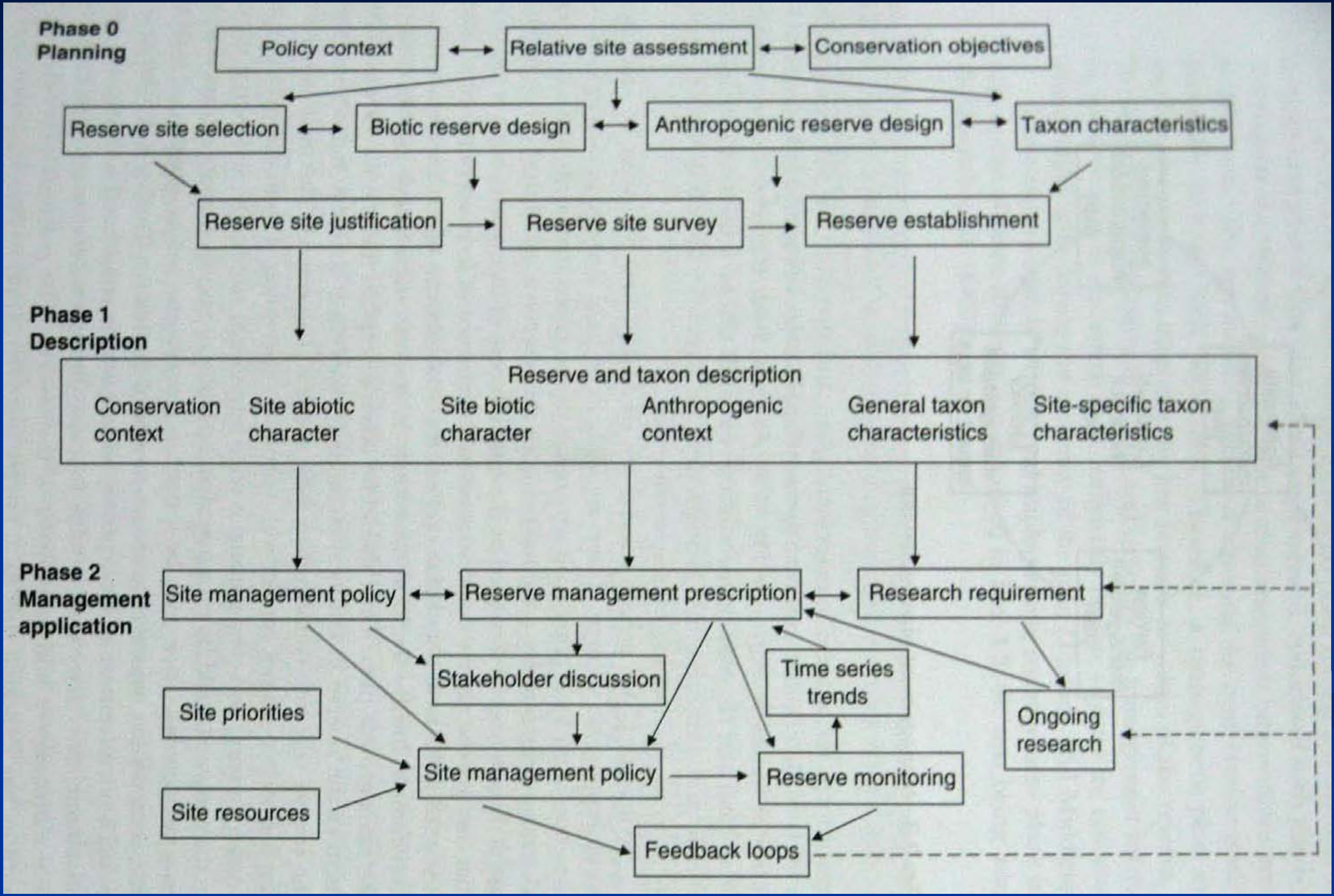
The local communities requirements need not conflict with scientific conservation.

Traditional utilization (harvesting, hunting and even grazing) is often intrinsically sustainable and even if restricted in the core area could be encouraged in the buffer or transition zones though regulation may be require.

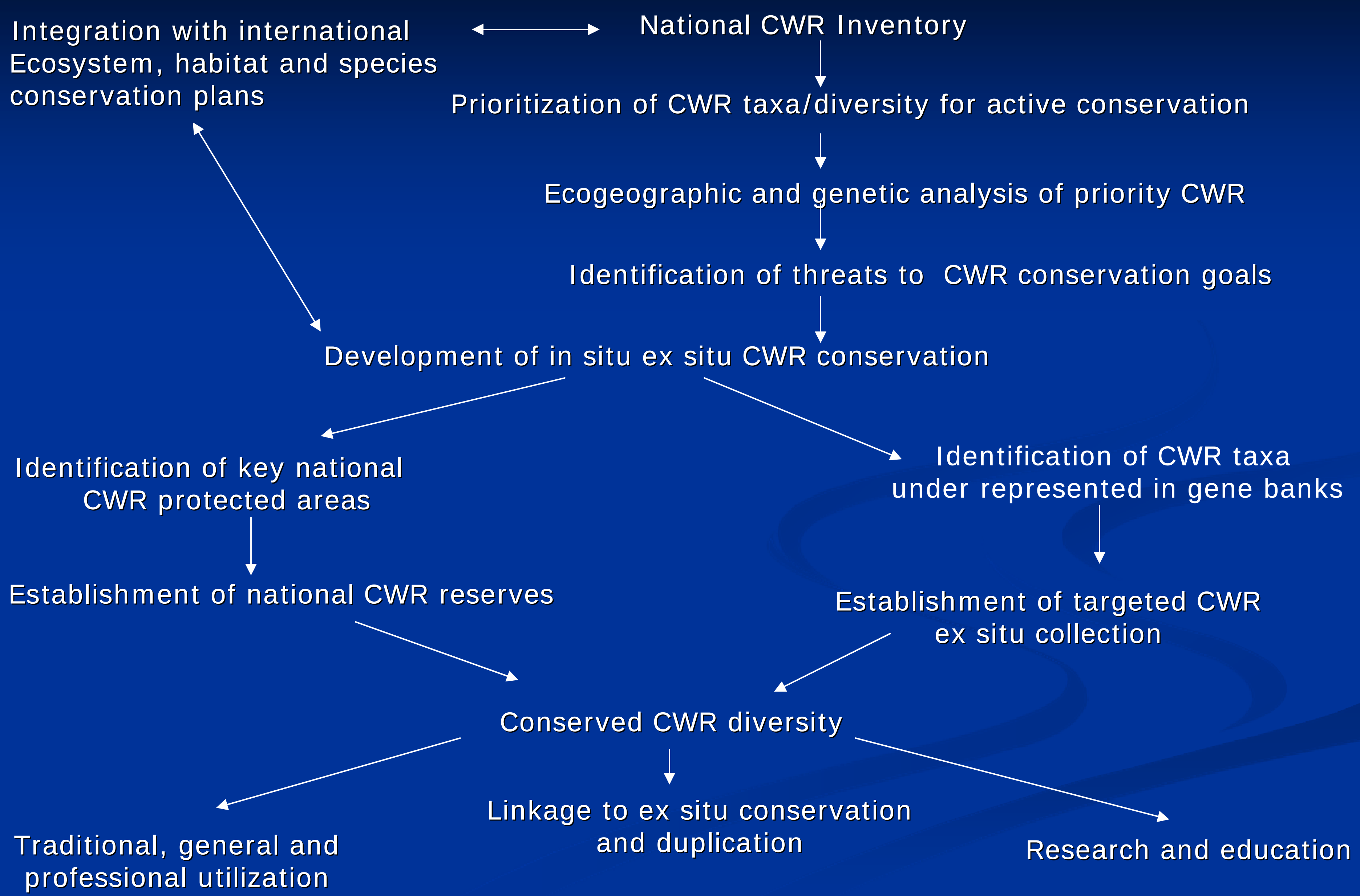
There may be a need to compromise between traditional utilization and conservation objective to ensure success of the reserve.

A management plan should be a succinct document that identifies the key features or values of the reserve, elucidates the management objectives to be met and indicates the management interventions to be implemented.

Process of compiling a genetic reserve management plan



Model for development of national CWR strategy



C. Plant population monitoring methodologies for the in situ genetic conservation of CWR

1. Monitoring design
2. Data recording and monitoring documentation system
3. Demographic and ecological monitoring methodologies
4. Genetic monitoring methodologies

Plant population monitoring can be defined as the systematic collection of data over time to detect changes in relevant plant population or habitat attributes, to determine the direction of those changes and to measure their magnitude.

For in situ genetic conservation of CWR populations, the objectives will normally relate to the maintenance of the initial levels of genetic diversity in the target population and the assurance of the viability of the populations from demographic, genetic and ecological perspectives.

In is important to make a clear distinction between monitoring and research. While monitoring detects change in parameters, research is normally oriented to determining the cause of same patterns or process observe.

Population monitoring focuses on the target taxon and measures aspects such as population size, structure, frequency, density and cover.

Habitat monitoring uses indicators that describe how well the objectives for habitat management are met by the current practices.

The latter approach may be of interest when management activities to conserve a population are based on improving habitat conditions for the species.

Habitat monitoring may, however, provide indirect information by demographic data.

The measured change in characteristics of the habitat can be directly related to population change.

1. Monitoring design

Identification and selection of variable that can be monitored

The types of variables to be monitored should be identified and selected in order to answer the question posed. In CWR conservation, monitoring will require information on:

- **demographic parameters** – used to asses the viability of the population to estimate population trends, extinction risk and minimum population viable (MVP) size.
- **ecological parameters** – should be able to identify changes in the physical conditions that operate in the population and characterize the dynamics in the composition of communities associated with target CWR.
- **genetic parameters** – may be important for evaluating the genetic diversity contained in the population as well as for understanding the genetic processes that take place in the dynamics of the population.

The final goal of CWR conservation is to be able to maintain and provide a sources genes that can be applied in crop breeding. Therefore, particular attention must be paid to those processes that lead to genetic erosion and genetic pollution.

Census and sampling design

A census of the population counts or measures each individual. In many situation counting or measuring all individuals of the population is not practical and it necessary to use sampling methods.

The type and size of sampling unit depend on the variable that is being measured.

The most efficient size and shape of the sampling unit depends on the spatial distribution and density of the target population, edge effect, ease in sampling and disturbance effects.

When the monitoring objectives is to estimate some parameter in a population, the estimate obtained can be compared to a target or threshold value to determine if the management objectives is met.

Thus, when monitoring is based on a sampling strategy, monitoring objectives should include specific information such as levels of precision, acceptable levels of power and false-change error rate or minimum detectable change.

Selection of sampling units

Pilot sampling involves taking observations within areas of standard size, usually called **quadrats**.

Quadrats are usually square or rectangular, although circular quadrats have smaller edge effects.

- Small quadrats – portable wood or metal frames
- Larger quadrats – can be demarcated by pacing out or measuring the sides using a tape measure, placing pegs or stakes in each corner, and running string or colored tape around the perimeter.

Positioning sampling units

When sampling is used to characterize one or more parameters of the CWR target population or its habitat, the question arises of how to position the sampling units in the population.

The most important requirement is the use of random sampling method. The sampling units must be distributed throughout the whole area of the target population for adequate representation.

The most commonly methods of random sampling are:

- Simple random sampling
- Systematic sampling
- Stratified random sampling

Pilot studies

Once the monitoring study has been designed, a pilot study should be carried out to test the efficiency of the field technique and assess the experimental design.

On evaluating the field data from the pilot study, one may find that the sample size is inadequate for detecting change or that statistical confidence levels are not obtained. At this stage, modifications can be made in the selected methods, saving a lot of time, effort and cost in the long term.

2. Data recording and monitoring documentation system

A very important part of any monitoring programme is the development of a data recording and documentation system. The designed monitoring methodology should be clearly documented so that it can be followed by other reserves or by different technical staff within the same reserves.

In the genetic reserves conservation of CWR it may be very useful to follow the data structure used in Crop Wild Relative Information System (CWRIS) in the framework of the European Crop Wild Relative Diversity Assessment and Conservation Forum

www.pgrforum.org

3. Demographic and ecological monitoring methodologies

1. Demographic parameters

The main purpose of including demographic parameters in the monitoring CWR in genetic reserves is to assess the viability of the target population – to determinate if population size is declining or stable and to what extent the population faces extinction.

- ***Population size*** - can be determined through a census (if population have below 5000 individuals) and use sampling methods (if is a larger population).
- ***Density of population*** – from a CWR perspective ideally is counting individuals that correspond to distinct genetic entities.
- ***Frequency*** – is a percentage of plots occupied by target species within a sampled area. This parameter is appropriate for monitoring annual CWR, whose density may vary dramatically from year to year, but whose spatial arrangement of germination remains fairly stable. Is also good measure for monitoring invasive species that may pose a threat to a target CWR population.
- ***Cover*** - is the percentage of plot area that falls within the vertical projection of the plants of the target species. This parameter it is highly correlated to biomass or annual production and it matches the contribution of the species that are very small, but abundant, and species that are very large, but scarce.
- ***Population structure*** – is an important feature to monitor in a population. Usually, populations are structured by age, size or stage. An ideal structuring variable will be highly correlated with all vital rates of a population, allowing accurate prediction of an individual's reproductive rate, survival and growth.

- **Vital rates** – Along with current population size, population viability essentially depends on the vital rates of population. There are three types of vital rates can be identified:

  - survival rates – is proportion of individuals at one census that are still alive at the next census.

  - growth rates – can estimate probability that a surviving individual moves from its original class to each of the other potential class.

  - fertility rates – is average number of offspring that individuals in each class produce during the interval from one census to the next.

Gather data on the phenology of the population (reproductive structures – flowers, inflorescences, fruits), number of viable seeds, total fruits production per plant and total seed production, censuses of pollinators, seed dispersal, germination and dormancy of seeds.

The whole population or representative sample of the population must be individually monitored to obtain data on vital rate. Individual to be monitored are marked (inserting a tagged stake into the ground next to each individual) in a way that allows them to be re-identified at subsequent censuses.

- **Spatial structure** – provides information on the location of each individual – estimating the area of occupancy and assessing the relevance of within-population and intraspecific competition and facilitation. Use GPS .
- **Selection and use of demographic parameters** – This parameters are used in monitoring and will depend on the status of the target CWR population, the species life form and characteristics, and the planned data analysis.

2. Ecological monitoring

Ecological monitoring identifies changes in the physical conditions that operate in the population and characterize the dynamics in the composition of communities associated with target CWR.

The microhabitat of plant populations is made up of many biotic and abiotic components and their importance varies in both space and time.

- **Abiotic components** – decision about which components of the physical environment to measure will largely depend on the microhabitat of the CWR target population and the existing threats.

  - climate – is usually describe in terms of the familiar elements of the weather: *temperature, precipitation, solar radiation, wind, cloud cover, atmospheric pressure and humidity*.

  - soil – moisture, texture, ph, nutrients, salinity, redox potential and cation exchange capacity.

When these elements are measured systematically at a site over a period of several years, an accurate summary of the climate of the genetic reserve can be obtained.

- **Biotic components** – comprise the living components of plant's habitat.

Plant communities in the microhabitat is the best describe by obtaining density, cover and frequency values for each species as defined in before slides.

Parameters and equation for monitoring plant community structure (Cox, 1990)

Density = no. of individuals / area sampled
Relative density = (density for a species / total density for all species) × 100
Dominance = total of basal area or aerial coverage values / area sampled
Relative dominance = (dominance for a species / total dominance for all species) × 100
Frequency = number of plots in which a species occurs / total number of plots sampled
Relative frequency = (frequency value for a species / total frequency values for all species) × 100
Importance value = relative density + relative dominance + relative frequency

The detection of significant changes in any of these variables through time may be a clear identification of changes in the habitat that may be affecting the viability of the target population

Among mutualists, pollinators and seed dispersers are essential components of reproductive process of many plants.

Reproductive success of the target CWR species may be greatly dependent on the availability of these plant mutualists.

You must inventories and censuses of these animals in a monitoring programme (information on density and frequency).

Plant predators and parasites must be monitored – gathering data on density and frequency for each species.

The presence of pathogens in plants can often be determined by standard visual observation (symptoms include changes in leafs colour, mottling, burns stem and shoot damage).

- **<u>Disturbance and control sites</u>** – in additional to the above mentioned parameters, ecological monitoring should report any natural or human induced disturbance.

  - <u>natural disturbance</u> – fire, flooding, slope movement, wind damage, extreme temperatures, trampling by animals and erosion.

  - human causes of disturbance - mining, logging, domestic livestock grazing, recreation, road construction or maintenance and week control.

- **<u>Climate change</u>** – CWR monitoring in genetic reserves must be capable of detecting and predicting changes in species composition and plant dispersal caused by climate change, habitat destruction and altered disturbance regime.

Species level impacts can be evaluated by tracking the distributional ranges of species over time as well as timing of seasonal cycles and population growth rates.

Species to be used as indicators of climate change include those with distribution, physiology or life cycles that are sensitive to climate (especially temperature and precipitation) but less vulnerable to other environmental changes such as land use shifts and pollution.

<u>Common changes</u>: earlier shooting and flowering, fruit ripening, hibernation, breeding and migration.

Changing climate conditions can also cause changes in species composition through the replacement of a dominant species by a more tolerant subdominant species (is situ conversion).

3. Timing and frequency

Accurate monitoring results are also dependent on the timing and frequency of monitoring.

Monitoring is most effective when it is timed to the seasons in which the target species is easiest to locate.

- When must be monitored:

- species are in flower
- in fruiting stage

- How often a target population should be monitored depends on :

- the life form of the species
- the expected rate of change
- rarity and trend of the species
- the resources available for monitoring

However, the main determinant of the frequency of sampling may be the strength and nature of the perceived threat to the population.

4. Consistency

Data collection methods need to be consistent throughout each census or sampling of target CWR population. The methods must be carefully written out so that measurements taken in successive time steps are done in the exact same manner.

If a team is carrying out the monitoring, each member of the team needs to be clearly instructed and trained on the methods to be followed.

5. Data analysis

Once field surveying is completed, the data provided by the monitoring process need to be properly analysed to be able to reach meaningful conclusion.

Statistical tests to analyses information will be chosen when the monitoring programme is designed, observing that assumption for proper use of the tests are met.

It is also important to analyses data after each monitoring cycle. Timely analysis can identify problems early on and ensure that question require additional field visit or different methodology can be addressed.

One of the most essential data analyses for genetic reserve management is target CWR population viability analysis (PVA).

Population viability analysis

PVA is use of demographic modelling methods to predict the future status of a population and help make conservation and management decisions.

4. Genetic monitoring methodologies

The aim of plant genetic conservation is often started as being to conserve, as far as possible, the range of genetic diversity found in a target species.

This aim recognizes that genetic diversity is a critical component of biodiversity and that the genetic resources themselves are a rich potential sources of useful genetic traits.

However, in additional to the preservation of genetic material, genetic conservation needs to maintain the evolutionary process.

Genetically based approaches to conservation monitoring ca, therefore, only be applied to the most highly prioritized taxa, and only after proxy or surrogate measures of genetic diversity have been applied.

1. Key population genetic issues and parameters

- **Fitness** – reproductive fitness is the measure of individual's ability to contribute offspring or progeny to the subsequent generation. Traits contributing to fitness are generally quantitative traits and are, therefore, difficult to measure.

Significant reduction in fitness traits associated with viability or fecundity are obviously undesirable, and so a minimum population size needs to be maintained to reduce inbreeding depression to an acceptably low level.

Maintenance of heterozygosity in a population which is not necessarily of adequate minimum size, and also its fitness, can be achieved by gene flow from other populations, provided that the genetic diversity that is introduced in this way does not contain maladaptive genes.

Environmental conditions will obviously affect fitness, but not in an easily measurable way.

Environmental change may gradually eliminate a population, or the population may be able to maintain its fitness by adapting to the change, but this will depend upon adequate levels of genetic variation existing in the population

- **Effective population size**

Can be defined as – the size of an idealized (hypothetical) population that would lose genetic diversity at the same rate as the actual population (the one under study).

Population of plants often vary in size from one generation to the next.

The number of genes that individual plants contribute to the next generation is rarely random, some producing much more seed than other.

All this factors make populations genetically smaller than their actual or census size.

Ne – effective population size

N – actual population size

<u>*Ne* will be closest than *N*</u> - in very large outbreeding populations, where all plants produce roughly the same number of seed and number of plants remain more or less constant from one generation to next.

<u>*Ne* will be much smaller than *N*</u> – for species that are substantially inbreeding, where a few plants produce most of the seed or where a population suffers temporary, a drastic reduction in number.

- **<u>Genetic diversity, gene flow and population structure</u>**

The concept of diversity:

- <u>richness diversity</u>: the total number of genotypes or alleles present within germplasm regardless of frequency
- <u>evenness</u> of frequencies of different alleles or genotypes.

Where richness is used to measure diversity, germplasm with more (and different) alleles or genotypes will be more diverse.

Where evenness is considered important, a germplasm sample where the alleles or genotypes are all roughly equal in frequency will be more diverse than one where there are same number of alleles or genotypes, but where they are very unequal in frequency.

- **Minimum viable population (MVP)**

  Minimum MVP – in which inbreeding depression is reduce to an acceptably low level – 50 individuals

  Optimum MVP – 500 individuals should be of sufficient size to allow new variation arising from mutation to replace that lost by genetic drift.

This is "50/500" rule

When you dealing with natural population you have:

Ne – effective population size

N – actual population size

Allowing ***"50/500" rule*** then becomes the 500/5000 rule, so the MVP size of 5000 is probably reasonably safe, but is tentative and could be reduce if better estimate of the *Ne*/ *N* ratio were available for the species and showed that *Ne* was indeed close to *N*.

Analysis of the factors that make *Ne*/*N* less than one shows that fluctuation in population size is the most important .

2. How, when and why to use genetic monitoring

- **How and when to use** - for molecular population genetic studies, random samples of leaves from individual plants can be taken.

Sampling 50 plants is generally considered to be adequate, but useful results can be obtained by sampling as few as 20.

If you have subpopulation this would need to be taken into account, with 20-50 plants being sampled from each.

- **Why to use** – if population monitoring is being for various reasons such as during management of an existing protected area, or in order to determine, what population should receive protection , you must know:

- to recognize situation where an overall reduction of fitness of a population might occur – where levels of gene diversity in candidate population can be compared using molecular markers before or during reserve design, those populations that more susceptible to future reductions in fitness can be identified because may have reduced levels of genetic diversity compared to others.
- to determine (in a pilot study ahead of protection) the extent to which a species is inbreeding or outbreeding (variation is partitioned mostly within populations and very little between – most populations may well possess as much as 80% of the total variation).
- To determine which inbreeding populations should be chosen for protection – which ones possess the most genetic variation. Easier and cheaper alternatives will be to undertaken an ecogeographic study to identify those populations which are most likely to contrast in terms of ecogeographic adaptation and hence, be most genetically diverse.

If populations have different intraspecific taxa or which are identifiable as being morphologically different and a result possibly af microspeciation could be chosen for protection without the need to resort to molecular population genetics.

- When there must be, for whatever reason, a choice between which small isolated populations (whether inbreeding or outbreeding) should be protected, there is a very clear need to use molecular population genetics to help in the decision making.
- What to do if a population being protected or being considered for protection has been subjected to a sever decline in population size. Molecular population genetics could tell as whether the population has suffered a decline in genetic diversity or a decrease in observed heterozygosity (provide that we have something to compare with an initial assessment of genetic diversity or a larger population elsewhere).
- How often should we undertaken our regular population monitoring – is almost certainly unnecessary to carry out routine monitoring, but it may be worthwhile undertaking a initial population genetic analysis of a sample of plants from the population(s) to be conserved.
- If the population are fragmented or become fragmented within a protected area or reserve, it is possible to establish the extent to which gene flow occur between the fragments and, therefore, how vulnerable they may be to loss of fitness.

In summary

Do not plan to do molecular population genetic monitoring first in any in situ conservation assessment.

Do not undertake molecular population genetic assessment/monitoring without very good reason, or without specific question to answer, and until other proxy genetic assessments have been fully examined.

Do not necessarily plan for routine sequential molecular population genetic monitoring

Do use molecular population genetic assessment as a last resort and for fine tuning to:

- select the most suitable and fittest population for in situ conservation
- measure inbreeding/outbreeding in a species as a pilot survey
- monitor population or critical situations
- Select for conservation among candidate populations of inbreeding species
- Select the "best" small isolated population for protection
- Determine the effect of a severe drop in actual population size on genetic diversity
- Establish whether gene flow is occurring between fragmentes populations.

Summary of procedure involved in in situ genetic conservation of wild plant species

1. **Selection of target taxa** - decide which species need active conservation and which in situ genetic reserves is appropriate.

2. **Project commission** - formulate a clear, concise conservation statement establishing what species, why and where the species are to be conserved.

3. **Ecogeographic survey/preliminary survey mission** - collation of the basic information for the planning of effective conservation and survey the distribution of taxonomic and genetic diversity, ecological requirements and the reproductive biology of the target species over its entire geographic range.

4. **Conservation objectives** - formulate a clear, concise set of conservation objectives, which state the practical steps that must be taken to conserve the species, and propose how the conserved diversity is linked to utilization.

5. **Field exploration** - visit competing potential sites indicated as having high levels of target species and genetic diversity by ecogeographic survey.

6. **Conservation application for in situ genetic reserves**

- reserves planning and establishment
- reserves management and monitoring
- reserves utilization

7. **Conservation products** - these will be populations of live plants held in the reserves, voucher specimens and passport data associated with the reserves and plant population.

8. Conserved product deposition and dissemination - the main conserves products, the plant populations of the target taxon, are held in the reserves. There is need for safety duplication and a sample germplasm should also be periodically sampled and deposited in ex situ collection – gene bank, field gene bank, botanical garden, etc with appropriate passport data.

9. Characterization/Evaluation the first stage of utilization will involve the recording of genetically controlled characteristics (characterization) and the material may be grown out under diverse environmental conditions to evaluate and screen for drought or other tolerance, or the experimental infection of the material with diseases or pests to screen for particular biotic resistance (evaluation).

10. Plant genetic resources utilization – the conserved material is likely to be used in breeding and biotechnology programmes, provide food, fuel, medicine, industrial products, as well as a sources of recreation and education. Locally the materials held in the reserves may have traditionally been used in construction, craft, adornment, transport or food.

This form of traditional utilization of the reserves by local people should be encouraged, provide it is sustainable and not deleterious to the target taxon or taxa, as it is essential to have local support for conservation actions if the reserves is to be sustainable in the medium to long term.

Model for Genetic Reserves Conservation of CWR species

Phase 1 ***Reserve planning and establishment***

Site assessments

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Assessment of local socio-economic and political factors

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Reserves design

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Taxon and reserve sustainability

↓

Formulation of the management plan

↓

Phase 2 ***Reserves management and monitoring***

Initiation of reserves management plan

↓

Reserves monitoring

↓

Community interrelationships

↓

Phase 3 ***Reserves utilization***

Traditional, general and professional utilization

↓

Linkage to ex situ conservation, research, duplication and education

Reserve planning and establishment

Site assessments

Ensure that each reserves represents the fullest possible ecological range (micro niches) to help ,secure maximal genetic variation and to buffer the protected population against environmental fluctuations pests and pathogens and man made disturbances.

As part of this evaluation prepare a vegetation map of the area surveying in detail the plant communities (and habitats) in which the target species grows

Assessment of local socio-economic and political factors

Constraints ranging from economic to scientific and organizational will affect the establishment of the reserves.

The simplest way forward in economic and political terms is for countries to take action on establishing a series of national parks or heritages sites, as this is likely to be of some benefit to the peoples of the countries and will gain their support

Reserves design

Sites should be large enough to contain 5000 – 10,000 individuals of each target species to prevent natural and anthropogenic catastrophe causing severe genetic drift or population unsustainability. Site should be selected to maximized environmental heterogeneity.

Each reserve site should be surrounded by a buffer zone of the same vegetation type, to facilitate gene flow and also where experiments on management regimes might be conducted and visits by the public allowed, under supervision.

Taxon and reserve sustainability

Establishing and managing an in situ genetic reserves is resource – expensive and therefore both taxon and reserve must be deemed sustainable over an expended period of time or the investment will forfeited.

Formulation of the management plan

The reserve site would have been selected because it contained abundant and hopefully genetically diverse populations of the target taxon.

Therefore, the first step in formulating the management plan is to observe the biotic and abiotic qualities and interaction at the site. Once these ecological dynamics within the reserve are know and understood, a management plan that incorporates these points, at least as they relate to target taxon, can be proposed.

Reserves management and monitoring

Initiation of reserves management plan

It is unlikely that any management plan will be wholly appropriate when first applied; it will require detailed monitoring of target and associated taxa and experimentation with the site management before a more stable plan can evolve.

The plan may involve experimentation with several management interventions (a range of grazing practices, tree-felling, burning, etc) within the reserve to ensure that the final plan does meet the conservation objectives, particularly in terms of maintaining the maximum CWR species and genetic diversity.

Genetic reserves conservation is a process oriented way of maintaining genetic resources; it will maintain not only the evolutionary potential of the population but also the effective population sizes of the CWR species.

Reserves monitoring

Each site should be monitored systematically at a set time interval and the results feedback in a iterative manner to enhance the evolving management regime. The monitoring is likely to take the form of measures of CWR taxon number, diversity and density as measured in permanent transects, quadrats,etc.

Community interrelationships

<u>Reserves utilization</u>

Traditional, general and professional utilization

Humans generally conserve because they wish to have actual or potential utilization options; therefore, when designing the reserves it is necessary to make an explicit link between the material conserved and that currently or potentially utilized by humankind.

There are three basic user communities: traditional or local, the general public and professional users.

Linkage to ex situ conservation, research, duplication and education

Different steps for an ecogeographic survey or study

Phase 1 **Project design**

Project commissioning

Identification of taxon expertise

Selection of target taxon taxonomy

Delimitation of the target area

Identification of taxon collections

Designing and building the ecogeographic database structure

Phase 2 **Data collection and analysis**

Listing of germplasm conserved

Media survey of geographical, ecological and taxonomic data

Collection of ecogeographic data

Selection of representative specimens

Data verification

Analysis of geographic, ecological and taxonomic data

Phase 3 **Production**

Data analysis

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Ecogeographic database | Ecogeographic conspectus | Ecogeographic report

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Identification of conservation priorites

4. Global strategy for CWR conservation and use

The conservation and use of CWR involves a plethora of governments agencies, NGOs, universities, commercial enterprises and other institutions at the national level.

The strategy essentially provider an action plan for nations and regions to refer to in addressing the critical issues of effective CWR conservation and use. The main objectives of the strategy are:

- Prepare national CWR strategic action plan
- Prepare national CWR inventories
- Establish a global mechanism for CWR conservation and use
- Create national priority CWR lists and identify priority CWR sites
- Create regional and global CWR priority lists and identify priority CWR sites
- Establish protocols for CWR information management and dissemination and provide national and global CWR information management systems
- Develop effective means of conserving and using CWR in situ
- Develop effective means of conserving and using CWR ex situ
- Assess CWR conservation and threat status
- Ensure effective security and legislation for CWR
- Promote sustainable utilization of CWR
- Initiate education and public awareness programmes on the importance of CWR.