Methodological Framework
for

Land Degradation Assessment in Drylands (LADA)
(simplified version)

Report on a Consultancy as Visiting Scientist
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Foreword and acknowledgements

This report is based on the work of Raul Ponce-Hernandez, as visiting scientist (July-August, 2004) at AGLL of FAO and Parviz Koohafkan, Chief of AGLL, FAO. The report is based on the content of an earlier draft of a methodological framework for LADA (Ponce-Hernandez, 2002), and the draft of the “Guidelines for a methodological approach for LADA” by Koohafkan et al (2003). The report also draws substantially from the report by Rebecca Dixon (2003), the unpublished work carried out by Matranga and Bunning (2004) and miscellaneous conceptual materials from The Millennium Ecosystem Assessment (Millennium Ecosystem Assessment Secretariat, 2003).

The report stems out of the desire to count with a simplified version of an earlier draft of a methodological framework for LADA prepared by the first author. The visiting scientist assignment at AGLL of FAO in Rome, allowed for attempting at simplifying the content of the earlier draft, while adding important content concerning the architecture and structure of the framework. The report enjoyed the benefit of discussions and contributions from many people, but outstandingly from Parviz Koohafkan, Hubert George, Sally Bunning, Jose Benites and Jacques Antoine at AGLL, from John Dixon at AGS of FAO, and from Rebecca Dixon of Environmatics Inc, in Canada.
Summary

A Methodological Framework for the assessment of land degradation in drylands (LADA) at multiple scales, form local to global, is proposed in this document. The framework is based on, and harmonized with the seven (7) steps of the LADA approach suggested by the guidelines for a methodological approach (Koohafkan et al, 2003). The methodological framework rests on a set of principles outlined in this document and it is based on the driving forces-pressure-state-impact-response (DPSIR) approach. It uses indicators of both, the land degradation state or condition and of its causes (i.e. driving forces and pressures) as the vehicle for the assessment. Thus, the framework describes procedures and methods for the analysis and integration of biophysical to socio-economic data on indicators of land degradation and its causes. The essence of the framework is a set of twelve (12) core activities to achieve assessment results. These are:

1. Define area and scale.
2. Select Indicators
3. Select methods, procedures and tools
4. Collect existing data and identify data gaps
5. Stratify or partition variability
6. Design a data collection strategy for missing data
   a. Designing a statistically-reliable sampling scheme on the basis of the strata or units and locate sampling sites based on the stratification.
   b. Collect data in the field (if applicable) from designed sampling sites and surveys, for the relevant indicators and scale of the assessment.
7. Analyze data
8. Integrate results
9. Identify “hot spots” and “bright spots”
10. Validate results and assess accuracy
11. Map out and report results
12. Monitor changes over time

The architecture, structure and the flexibility of the framework for application to dryland conditions anywhere in the globe, and therefore its adaptability and usefulness are predicated on the existence of a set of decision support systems to help users determine the appropriate set of indicators at the scale of the assessment, and the required tools and methods to achieve their measurement, modelling or estimation. A comprehensive “toolbox” of methods, procedures and tools furnishes the required methodological guidance and the tools for conducting an assessment at any scale and with any situation of data. These methods and tools range from manual and visual field assessment tools to sophisticated modelling tools and remote sensing. The integration of indicators into an assessment and the establishment of causality of a land degradation condition are achieved through establishing the networks of causal chains, whose implementation can be achieved either, manually or through automation, guided by the respective support system.
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LIST OF ACRONYMS

AGL  Land and Water Development Division, of FAO
AGLL  Land and Plant Nutrition Management Service (of the Land and Water Development Division, FAO) (incorporates former AGLS, Soil Resources and AGLF Fertiliser/Plant Nutrition Services)
AGLW  Water Resources Development and Management Service (of the Land and Water Development Division, FAO)
ASSOD  Asian Assessment of Soil Degradation (in full, Asian Assessment of the Status of Human-induced Soil Degradation in South and Southeast Asia)
CausE  Causality Engine or Tool (part of proposed Integration Decision Support System –IntDSS-of LADA methodological framework)
DPSIR  Driving Forces-Pressures-State-Impact-Response approach
DSS  Decision Support System
FAO  Food and Agriculture Organisation of the UN
GAEZ  Global Agro-Ecological Zones Assessment
GEF  Global Environment Facility
GEMS  Global Environment Monitoring System
GeoWeb  Georeferenced multi-scale spatial information system on the worldwide web (proposed for LADA info systems)
GIEWS  Global Information and Early Warning System on Food and Agriculture
GIS  Geographical Information System
GLASOD  Global Assessment of Soil Degradation
GM  Global Mechanism (of the UNCCD)
GRID  Global Resource Information Database
GTOS  Global Terrestrial Observing System
IDSS  Indicators Decision Support System (of LADA methodological framework)
IFAD  International Fund for Agricultural Development
IntDSS  Integration Decision Support System (of LADA assessment results)
IPE  Indicator Processing Engine (part of the purposed LADA IntDSS)
ISRIC  International Soil Reference and Information Centre
KB  Knowledge Bases
LADA  Drylands Land Degradation Assessment
MTDSS  Methods and Tools Decision Support System (proposed for LADA Methodological Framework)
NCC  Networks of Causal Chains (used in finding causality through Bayes Theorem)
NDVI  Normalised Difference Vegetation Index
NOAA  National Oceanic and Atmospheric Administration, USA
SDSS  Spatial Decision Support Systems
SOTER  World Soils and Terrain Digital Database
UNCBD  UN Convention on Biological Diversity
UNCCC  UN Convention on Climatic Change
UNCCD  UN Convention to Combat Desertification
UNCED  UN Conference on Environment and Development (Rio di Janiero, 1992)
UNDP  UN Development Programme
UNEP  UN Environment Programme
UNFCCC  United Nations Framework Convention on Climate Change
VFAT  Visual Field Assessment Tool (part of LADA “toolbox” and MTDSS)
WOCAT  World Overview of Conservation Approaches and Technologies
Chapter 1

Introduction, Aims and Objectives

1.1 Introduction

The present report provides simplified methodological framework for the assessment of land degradation in the drylands of the world. Its scope and applicability ranges from the global to the regional, national, and sub-national, watershed or basin and the local or village and farm plot levels. The framework relies on a set of principles, which are outlined in this document and which lend the framework its most salient characteristics, namely: reliance on indicators, flexibility through the use of modules (i.e. the “toolbox” approach), multi-scalar, reliant on the integration of bio-physical to socio-economic causative factors through the DPSIR approach (i.e. driving forces-pressures-state-impact-response). It integrates also the impacts of the states of degradation on the livelihoods of people, and the responses of such people to these impacts. The framework is flexible enough to allow for adaptations to the particular circumstances of the dryland environments, scale and socio-economic, cultural and political and technological settings of the area of its intended application. It can be considered as a first approximation, which would benefit from contributions derived from lessons learned through its application in real assessment situations.

1.2. Statement of the problem

Dryland resources are fragile ecosystems that represent the source of livelihood of a large population around the globe. It has been recognized by parties to the UNCCD that not enough is known about the nature, severity and extent of land degradation and about its causes and the responses that such degradation has prompted from land users in such fragile dryland ecosystems. Efforts to characterize and quantify the type, intensity and extent of degradation processes at multiple scales, in the past, have provided valuable data and information. Yet, many questions, particularly related to the linkage of the state of degradation to its causes (i.e. driving forces and pressures) and to its impacts on livelihoods and possible remedial responses, remain unanswered. There is an obvious and urgent need to incorporate what is known from present assessment methods to integrative paradigms, in order to answer pressing questions that decision and policy makers in drylands face, and for which they require immediate answers.

1.3. Aims and Objectives

The aims of the LADA methodological framework is to provide users with a reliable, flexible, quantitative and reproducible assessment framework of methods and procedures for application in the dryland areas of the world, in order to make them widely available, while demonstrating their applicability and building local capacities. The methods and procedures in the framework are to be validated through assessment activities to be
undertaken by countries in their dryland jurisdictions. The LADA methodological framework should be able to address the urgent need for accurate information about the extent and impacts of land degradation in drylands in order to assist the affected populations in designing appropriate interventions that will ensure the sustainability of livelihoods in these environments.

The LADA methodological framework, while considering the tested elements of past and present methodologies, it should integrate the bio-physical components of land degradation to the social, economic, cultural and policy contexts where degradation occurs for the identification of causes and responses to degradation as well as its impacts on livelihoods of rural populations.

The procedures of the framework suggested in this document attempt to provide further guidance, beyond the fundamental LADA approach seven (7) sequential steps suggested earlier in Koohafkan et al, (2003). Such steps are:

1. Preparation of initial studies;
2. Establishment of a national LADA task force;
3. Stocktaking and preliminary analysis;
4. Developing a stratification and sampling strategy;
5. Field survey and local assessments;
6. Development of a LADA decision-support tool
7. Development of a LADA monitoring tool

The seven (7) steps of the guidelines and the procedures suggested in this document should be considered as complementary. The suggested procedures in the framework described in this document provide a more detailed description of methodological options within the core set of activities, which are involved in the seven (7) steps of the LADA approach. It is the main aim of this document to provide a detail description of such core set of activities.
Chapter 2

Definitions

Before describing the principles of the framework, it is necessary to introduce definitions and terms that provide useful reference, scope and clarity of meaning. For the definitions of land, drylands, land degradation, and desertification the LADA Workshop (LADA Workshop Report, 2002) “recommended adoption of the UNCCD (Article 1) terminology and definitions as a basis, whilst ensuring harmonization with definitions in use elsewhere, such as those employed in the FAO Global Agro-Ecological Zones framework (GAEZ). Specifically, the UNCCD definition of land is effectively equivalent to that employed since 1976 by FAO. References in LADA documentation to “land degradation in drylands” are equivalent to the UNCCD definition of “desertification”.

Land

The definition of land adopted by LADA is “a delineable area, encompassing all attributes of the biosphere immediately above or below the earth surface, including the soil, terrain, surface hydrology, the near-surface climate, sediments and associated groundwater reserve, the biological resources, as well as the human settlements pattern and infrastructure resulting from human activity” (FAO, 1998).

This definition emphasizes the functional and systemic relationships among its attributes. The knowledge of these relationships permits the identification and delineation of land units whose understanding is essential in the analysis of the dynamic processes that intervene in land degradation. In the LADA framework it is an area actually delineated on the basis of both a recognizable pattern of attributes and functional relationships among these attributes through a holistic and integrated baseline inventory of the land, which should be a pre-requisite for the land degradation assessment.

Drylands comprise areas having a ratio of P/PET < 0.65, where P is precipitation and PET is potential evapo-transpiration. A further breakdown of this range yields definitions of “hyper-arid” (P/PET< 0.05) “arid” (0.05 < P/PET< 0.20) “semi-arid” (0.20<P/PET< 0.50), and “dry sub-humid” (0.50<P/PET< 0.65). “Susceptible drylands” are considered the arid, semiarid, and dry sub-humid regions of the earth (van Lynden and Kuhlmann, 2002).

Land degradation is a complex set of processes of impoverishment of terrestrial ecosystems under the impact of human activities. Land degradation can be understood as the gradual or permanent loss of productivity of the land resulting from human activities, mainly from the mismatch between land quality and the intensity of activities part of the actual land use.

The UN-CCD defines land degradation as a natural process or a human activity that causes the land no longer being able to sustain properly its economic functions or the original ecological functions (FAO 1998).
The manifestations of land degradation can be measured in terms of:

- Reduced productivity of desired plants
- Undesirable alterations in the biomass and the diversity of micro and macro flora and fauna (soil biodiversity)
- Accelerated soil physical, chemical and biological deterioration
- Undesirable alterations in ecosystem services
- Increased hazards for human occupancy

Land degradation in arid, semi-arid and dry sub-humid lands (drylands) resulting from various factors including climatic variations and human activities leads eventually to desertification.

**Desertification** has been defined in the United Nations Convention to Combat Desertification (UN-CCD) as land degradation occurring in arid, semiarid and dry subhumid areas caused by a combination of climatic factors and human activities. Hence only land degradation occurring in drylands as defined above is considered as part of a desertification process.

Land degradation is the subject of perception. For whom a land is degraded will depend on the perception or the baseline of reference by different people. Differences in perceptions of land degradation may occur between scientists and land users, and even between scientists of different disciplines. These differences in perception, particularly those from the land users themselves need to be accounted for into a holistic view.

The effects of climate change on land degradation are not yet well understood. However, it is clear that land degradation is a driver of climate change.

**Assessment** suggests judgement, evaluation or comparison. It makes necessary the definition of a baseline or reference level for the evaluation or comparison. This is a matter with practical implications since the reference level could change from place to place depending on the intensity of anthropic interventions in ecosystems.

**Baseline or reference level of land health.** The baseline level could range from “pristine ecosystems” to an extreme level of intervention and its associated state of degradation. For practical purposes, the characteristics (i.e. indicator variables) of an undisturbed/healthy soil (Bunning and Jimenez, 2003) in a similar ecosystem as that of the site of the assessment can serve as an initial reference point with acceptable allowances for shifts in the status of such indicators (usually less “healthy”) due to disturbance created by historical cropping and pasture regimes imposed on the initial undisturbed/healthy soil.

Since the central objective of the framework is to suggest a set of methodological pathways and tools to assess and quantify the extent and severity of land degradation in dryland areas and its causes and impacts so as to suggest remediation actions associated to the causes and impacts, it is important to define the terms “extent” and “severity”.

Extent indicates distribution in both, spatial and temporal dimensions. Typically the mapping of the spatial dimension is the foundation for the monitoring of temporal variations.

Severity refers to the intensity of the process or state of degradation and suggests the definition of a scale of intensity, whether categorical or numerical, continuous or discrete.

The assessment of land degradation as understood in this framework, includes references to its causes: the natural processes and human activities that give rise to land degradation. The current assessment of land degradation for which this methodological framework is intended, is broader in scope and more complex than most past assessments (e.g. GLASOD, Oldeman, Hakkeling and Sombroek, 1992; UNEP’s Desertification Atlas, 1992; and the more detailed ASSOD study, UNEP/ISRIC/FAO, 1995). These generally were bi-physical in nature and only limited to the identification of the primary process of degradation (e.g. water or wind erosion) and a few causative land use factors (e.g. overgrazing). The LADA framework aims at assessing, at the same time with the states of degradation, the causes, status and impacts of land degradation and possible responses. Therefore these causes need to be characterized and evaluated.

Causes are the direct agents that promote change resulting in a given state of land degradation. Causes are the direct pressures exerted on land resources under which the onset of degradation or deterioration processes occur. These pressures are, in turn, caused by driving forces of a variety of origins (i.e. economic, social, political, etc.), which can be understood as indirect causes of land degradation.

Establishing causality usually demands a deep understanding of the dynamics of the systems (economic, social and cultural and their bearing on the biophysical), and above all of their interactions as they express themselves in the particular geographical location. The identification of causality through the dynamics of a natural or managed system necessitates of mapping the networks of causal chains from states of degradation to the pressures exerted on the resource and on to the driving forces causing the pressures. This is achieved in the methods of the LADA framework via mapping the linkages between direct indicators of the state of degradation to the direct pressure indicators and up to those of driving forces (indirect indicators). So, a causal chain is established. Several causal chains may be linked or rely on similar indicators creating a network. Thus, the networks of causal chains connect the state of degradation to its causes.

The identification of the direct causative factors or pressures on the land, in some cases may be relatively straightforward. In others, due to the working scale or to the resolution of the data, or where there are no evident indicators, it may involve more exhaustive investigation. Among the straightforward identification of direct causative factors, for instance, inappropriate or over-intensive land use and land management practices are often the most important factor of land degradation in drylands. Livestock grazing in high densities and with static grazing patterns may alter floristic composition, reduce biodiversity, increase soil compaction and in extreme cases eliminate vegetation cover altogether (White, Tunstall and Henniger, 2002). Fire, whether natural or induced may
affect vegetation density and diversity. The encroachment of urban centres and human settlements permanently inhibit the natural functions of drylands, while at the same time increasing the pressure on the surroundings for increased services such as water, sanitation and waste disposal. The creation of impervious surfaces by paving and compaction of the soil, changes the drainage pattern inhibits groundwater recharge and leads to increased runoff.

**Impacts** in the LADA framework refer to changes on the different aspects of people’s livelihoods imposed by the state of land degradation and its causes. These impacts manifest themselves on the multiple functions of the land, which include providing food and fibres and a livelihood for people, serving as a buffer between the atmosphere and underground water resources, providing mineral and organic resources, storing carbon and preserving biological diversity, providing support for infrastructure, opportunities for tourism and being a repository of archaeological values. This suggests that multiple components of a system made up by capitals (natural, financial or economic, social, cultural, human) may be affected by the degradation processes. The changes imposed by land degradation on all these aspects, which are characterized here as impacts, must be significant and measurable or appreciable.

Examples of impacts of land degradation are:

- The decrease of land quality, which in turn brings a decrease in land productivity and has an effect on the livelihoods of people in terms of food insecurity, poverty and migration.
- The reduction of habitat for living species, both, macro and micro flora and fauna.
- The impact of degradation on the likely increase on Greenhouse Gases (GHG) emissions, for example, the increase in carbon emissions through the oxidizing of organic matter induced by tillage.
- The likely impact of land degradation on ecosystem functions and landscape processes such as water and nutrient cycles, which in turn affect water availability and primary productivity of ecosystems and their services to populations.
- The decline on the buffering capacity of soils, giving way to undesirable changes that may directly affect in land productivity.
- The impact of degradation on the biodiversity of ecosystems at many levels, above and below ground.

The methods part of the LADA framework were developed not only to assess or evaluate such impacts, but also make the connections between those impacts as they express themselves in the deterioration and even eventual loss of livelihoods, extreme poverty and even human disaster.

**Responses** are understood in the LADA framework as the direct or indirect actions taken by land users and managers to the impacts on their livelihood caused by the state of land degradation, the pressures on the land causing such state, and the driving forces causing such pressures. Such responses may manifest themselves as possible remediation actions. The experience of land users themselves, who run informal “experiments” with nature through their responses in their particular lands, accrue knowledge and experience
(i.e. “indigenous” or traditional knowledge) about remediation actions. Considerations of knowledge transfer are part of the methodological framework through tools such as WOCAT.

**Indicators** are variables, parameters (even in the statistical sense), or measures which provides evidence of a condition, change of quality, or change in state of something valued (Dumanski and Pieri, 1996). Land quality indicators, for instance, include statistics that report on the condition and quality of the land resource itself. They may also reflect the cause-effect relationships that may result in changes in quality, and on the responses to these changes by society. **Index** is the result of the aggregation of several indicators according to some mathematical expression or formula.

FAO (2003) provides a comprehensive overview of possible indicators to be used. Several of these may prove quite useful for initial determination of specific degradation status, causes and impacts. Indicators may help in the assessment, in the collection of baseline information and in monitoring. These activities serve two purposes:

- to detect and identify the types of degradation and assess their severity; and
- to determine and analyse the cause-effect relationships involved with a view to identifying trends and taking remedial action.

**Approach** is the context of LADA is how to approximate undertaking the solution to a problem. It is how to set about solving a problem. The LADA guidelines for a methodological approach (Koohafkan et al, 2003) describe seven (7) steps to approximate or set about the LADA project implementation.

**Framework** is the structure, configuration, organization, arrangement, composition or skeleton of a collection of elements or entities, physical, conceptual or procedural. A framework is the make up and structure of that set.

**Methodological Framework** is a framework whose constituents are methods and procedures. A methodological framework provides the structure, configuration, organization and composition of methods and procedures to be used for a finite set of objectives.

The **LADA Methodological Framework** provides the configuration of constituent methods and procedures and their structure, organization and composition to carry out the assessment of land degradation in drylands, including the causes and impacts of such degradation. *It is the skeleton of methods and procedures.* In the LADA context, the methodological framework is the scaffold which provides the methods under a set of driving principles for the assessment. In this sense, the LADA framework leaves ample room for flexibility and adaptation to particular geographic, socio-economic, cultural and technological circumstances where the assessment of dryland land degradation is to be undertaken.
The LADA Approach vs. LADA Methodological Framework

It must be noted that the LADA approach must not be confused with the LADA framework. While the LADA approach provides the essential seven (7) steps to approximate or to set about or the way to undertake the implementation of the LADA project, the LADA framework described in this document provides the structure of methods and procedures to assess land degradation according to the LADA approach (the seven steps).
Chapter 3

The LADA Conceptual Framework

The conceptual part of the LADA framework places the states of land degradation in drylands as the central focus for the assessment, while recognizing that the elucidation of its causes (direct and indirect) are of paramount importance to the formulation of policies for its control and reversal. It equally places importance on the impacts that the current state of degradation has on dryland ecosystem services and how, in turn, these impacts too the livelihoods of people and their five capitals (natural, financial, social, human and physical). The conceptual framework of LADA rests on the Driving Forces-Pressures-States-Impacts-Response (DPSIR) approach to understanding the direct and indirect causes of the states, their impacts and the responses that people have generated to counter adversity caused by land degradation and the decrease in ecosystem function and ecosystem services (Millennium Ecosystem Assessment Secretariat, 2003).

The LADA framework also recognizes that the principles of the DPSIR approach operate at multiple scales and therefore that assessments at scales ranging from global to local and from local to global can be harmonized. Different manifestations of causative factors (driving forces and pressures) at different scales can be elucidated through their indicators at each scale, and that the evidence of the states of degradation and its impacts and responses will also be indicated by different variables at each scale. The conceptual part of the LADA framework is illustrated in figure 1.

![Figure 1. The LADA Conceptual Framework](image-url)
Chapter 4

Framework Principles

This section describes the fundamental principles on which the framework is predicated. The principles underpin the structure of the framework and its function and application. Such principles are deemed universal in that they should be applicable at all scales of assessment and under any circumstances of data availability and completeness, available technology and social, economic, cultural and environmental setting and contexts. In this sense, the framework principles are its structure. They are unchangeable and are reflected in the methods and procedures that are component of the framework. The description of these principles follows.

4.1. Complexity vs. reproducibility. Land degradation is a complex process and its causes and impacts are varied and multiple. To provide with reproducible and comparable assessment results, the selection from the framework of the methods and procedures to be employed are to be commensurate with the grain and completeness of the data available, the technology, tools and technical knowledge of the assessor. These should be stated as part of the assessment outcomes.

It is virtually impossible to escape from addressing the apparent contradiction between the complexity of the methods required to yield accurate, reproducible and therefore reliable estimates, and the need for an accessible (which requires a level of simplicity) and viable method. Powerful (thus maybe complex) analytical tools may be used when possible. On the other hand, over-generalization, and subjectivity are to be avoided since they often run against reproducibility, accuracy, consistency and therefore scientific soundness. According to data quality, technology and technical knowledge the tools from the framework should be selected and they should be reported as part of the assessment results. Ultimately, the methodology is to provide information for decision- and policy-makers. This should be born in mind by national teams executing the assessment.

4.2. Flexibility. The methodological framework should be flexible, since the problem of land degradation in drylands is too complex for a universal, standard assessment methodology. Flexibility and compatibility of procedures and methods with scale and data availability and resolution is paramount to the approach. Minimum data sets are necessary for the assessment. The flexibility of the framework rests on that it should be seen as a collection of methods and pathways to indicate how these methods are sequentially related in terms of data and information flows, inputs/outputs and in synchrony. The framework should be considered as a “toolbox” of methods and analytical tools, and procedures on how to use them. Users implementing the framework should take from it what is needed in their particular assessment circumstances. The flexibility allows also for adaptations to the particular circumstances of the assessment in terms of technical knowledge of the assessing team, data quality and completeness, idiosyncratic considerations and cultural backgrounds. Additions to the toolbox and modifications are possible as long as they are stated and a common reporting LADA...
language and legend are used, and they are declared. The framework is to provide the necessary flexibility, which would allow adapting it to a particular scale and to the ecological, technological and socio-cultural circumstances where it is applied.

4.3. System’s approach. The methodological framework uses a systems approach. The need to identify causes and responses within the bio-physical, social, economic and cultural contexts and at multiple scales and their interconnections makes it imperative the adoption of a system’s (i.e. ecosystems) approach so that the dynamics of the components involved are understood. A system’s (i.e. ecosystems) approach focuses on the interactions of the multiple elements of the process and therefore enables the mapping of the causal chains to states and impacts of land degradation.

4.4. Participatory. The methodological framework of this kind should be participatory in that it will attempt to build on the integration of knowledge and experience from multiple stakeholders, notably farmers, land users and practitioners in the field, but also natural, economics and social scientists, decision-makers and policy-makers. The involvement of multiple stakeholders in the knowledge generation, decision-making and implementation processes of land use and management, from local to global scales will enrich the methodological framework by incorporating their multiple perspectives.

4.5. Approximative, adaptive and recursive. The development of the methodological framework, given its participatory nature, will require successive approximations through an iterative process that incorporates new knowledge and insights at each stage, adapting to new circumstances and situations.

4.6. Indicative. The assessment will be based on “indicators”. In recognition of the low likelihood or feasibility of direct measurement of land degradation processes, or of the lack of available data, it will be necessary to use “indicator” variables to determine by “proxy” the nature and intensity of the status of land degradation. Indicators will be derived even from interpreting observations or commentary from farmers, land users and other stakeholders related to the status of degradation of their lands. In this sense the framework’s approach is indicative.

4.7. Multi-scale. Land degradation assessments at multiple scales will be needed and should be implemented. Assessments results at a one given scale should not contradict results at another scale but, rather, it should be possible to aggregate and disaggregate, upscale and downscale assessment results at multiple scales harmoniously. At each scale of the assessment the set of indicators (IS), from the suggested LADA set, applicable to that particular scale should be clearly identified and stated. Together with the indicator set at each scale, the applicable set of analytical procedures and tools (M) should be identified and declared (i.e. land cover changes as indicator of degradation detected by remote sensing may be quite useful at global, regional, national and watershed scales, but not necessarily so at the local level or at the farmer’s plot (figure 2). Similar reasoning applies to modelling tools, methods and procedures (M). Simulation of sediment and nutrient transport looses relevance within the field and modelling tools may not applicable at the national scale. The trade-offs between accuracy of results and data
resolution and completeness at the scale of assessment should be recognized and stated in the assessment report. The degree of accuracy of results should be fixed and standardized for all assessments as to allow for comparisons anywhere in the globe. The target accuracy of results should be the standard fixed for all assessments at the given scale, then as a function of the degree of completeness of the databases initially available for the assessment and the resolution of the data, the investment in assessment efforts and resources should be calculated in order to achieve the target accuracy. These issues and the issue of data completion should be clear to the assessment team and stated in the assessment report. An important consideration in this respect is that the link between local and national levels needs to be maintained. Causal factors of land degradation identified locally should also be extrapolated and taken into account nationally.

### Framework’s Multi-scalar Approach

![Diagram of Framework’s Multi-scalar Approach](image)

**Fig 2.** At each scale there is a suitable set of indicators (IS), models (Mod) and tools (M) that are applicable, and trade offs in: data resolution, accuracy, complexity of analysis, time and costs.

#### 4.8. Modular

The flexibility and the approximative nature of the methodological framework make it imperative to divide the totality of it into its logical parts in terms of modules. A modular methodological framework should be seen as a “toolbox” from which the appropriate methods, procedures and modelling tools should be drawn for the assessment from each module, depending on the aspect of the assessment being implemented. The modular LADA framework lends flexibility to the assessment approach and allows for adaptation to circumstances of data availability and technological background.
4.9. Managing variability or diversity. At any given scale, the assessment will confront significant spatial and temporal variability or diversity. So, in order to manage this variability or diversity and to understand the linkages between degradation and its causes, variability or diversity should be split in terms of identifiable functional units. This should allow for the assessment of manageable spatial and temporal units at each scale of analysis so as to develop and understanding of the dynamics of the system within. Then integrate before moving back to a greater level of generalization.

4.10. Based on empirical knowledge and practical experience. The land degradation assessment is intended for practical application: to identify causes of land degradation and possible remedial actions in a variety of dryland environments. Therefore it should be based on tested empirical knowledge and experience. This is on the premise that the farmer, herder or other land user has been running long-term informal experiments with nature, in a variety of adverse natural and anthropogenic conditions typical of dryland environments. The reliance on traditional knowledge will need to be compatible with the scale of the assessment. At national or global scales, for instance, there may be less reliance on this type of local knowledge and more on other types of indicators (e.g. vegetation cover dynamics). However, the framework should aim at incorporating, as possible, the vast amount of local, traditional or indigenous knowledge.

4.11. Focused on the provision of goods and services of dryland ecosystems. To be of practical use the results of the assessment ought to provide information on how land degradation is diminishing the capacity of dryland ecosystems to provide goods and services. The focus is on the economic, ecological, social and cultural services that the land provides and particularly on their variations over time and space.

4.12. Integrative in the interdisciplinary sense. Views of land degradation in past assessment efforts have been largely resource-centred or discipline-centred. This has hampered the full understanding of processes and causes of land degradation, and of the societal responses to it. Such understanding is essential for the formulation of useful information for decision-making purposes in tackling land degradation. A systems approach should be adopted for the integration of the different steps in the analysis.

4.13. Based on sound scientific principles. As far as possible the development of the framework should be based on current science and should make use of modern technology. The application of the framework should yield a set of results that are based on methods and procedures which, while as simple and accessible as possible, have sufficient rigour to be transferable, reproducible and consistent, allowing for regional comparison and compatibility of results at multiple scales.

4.14. Harmonized. LADA, being an international initiative, will promote methodologies and data and information bases that are compatible across countries and ecosystems. LADA aims at developing common concepts for data collection and analysis that enable the exchange of results and permit up- and downscaling among local, national, regional and global scales.
4.15. **Subject to quality control.** Even when harmonized methodologies are agreed upon and are applied, quality control is still necessary. Implementation of these methods depends on the expertise applied, the political will expressed and the financial resources made available. A mechanism is to be put in place that allows fixing standards of accuracy of results and assessing the quality of the data produced by LADA activities at different scales.

4.16. **Based on the Driving Forces–Pressure–State–Impact–Response (DPSIR) paradigm.** The methodological framework is based on the driving forces-pressures–state–impact–response (DPSIR) approach. This approach should be applied at all scales and levels of approximation in the assessment. The DPSIR approach allows for the elucidation and of the linkages between the driving forces behind the pressures on land resources that cause the current state of degradation, the impacts of such degradation on the other components of the environment and on human livelihoods, and the responses of land users to such state of land degradation and its impacts (figure 3). The DPSIR should allow for identification of causative factors and mapping of the linkages to the states (intensity) and types of degradation, all of which should be reflected in a mapping legend for spatial display purposes.

The DPSIR approach is the mechanism used for the LADA framework for the integration of the bio-physical to the social, economic, cultural and policy factors of land degradation, and is applied in the context of the interplay and trade-offs between the five capitals (natural, social, financial, physical and human).

4.17. **Results-based.** The methodological framework for the assessment is results-driven. The application of the framework will seek to provide concrete practical results of assessments in terms of data and information that stake-holders need for decision-making to respond to land degradation. In order to implement a results-driven approach, a problem-solving strategy of “working backwards” from the “deliverables” or “desired answers to questions”, to the “givens” or data available. Both, the questions for which answers are sought, and the available data need to be defined absolutely clearly by stakeholders in terms of the data and information required for decision-making. The results based approach would “walk backwards form final results to the “givens, filling in the steps required to convert the “givens” to the end result or “deliverables”, as illustrated in figure 4. This requires of three fundamental conditions: a). A clear definition of the data and information required as results from the assessment. b). The minimum data sets to attain meaningful practical results. c).The available data and the state of the databases to attain the target results that decision-makers require for policy formulation.
Figure 3. Illustration of the DPSIR approach in drylands

The Driving Forces-Pressures-State-Impact-Response Paradigm

- **Driving Forces**
  - Macro-economic policies
  - Land use policies
  - Development policies
  - Population growth
  - Poverty
  - Land use land tenure
  - Condition
  - Extreme climate events/change
  - Natural disasters
  - Water stress

- **Pressures**
  - Demands from agriculture, urban, etc. sectors
  - Nutrient mining demands for waste disposal
  - Population growth over cultivation, over grazing, demands for water uses

- **State**
  - Land productivity decline
  - Soil degradation & soil contamination
  - Soil erosion
  - Soil salinization
  - Loss of vegetation cover
  - Loss of biological diversity

- **Impacts**
  - Land productivity decline
  - Poverty and migration land
  - Goods and services
  - Water cycle and quality
  - Carbon storage capacity decline
  - Habitat destruction and loss of biodiversity
  - Change in human population size and spatial distribution
  - Other off-site impacts

- **Responses**
  - Macro-economic policies, land policies and policy instruments
  - Conservation and rehabilitation
  - Monitoring and early warning systems
  - Commitment to international conventions
  - Investments in land and water resources

**Driving Forces**

**Pressures**

**State**

**Impacts**

**Responses**
Fig 4. Problem-solving strategy ("working backwards") for the application of the LADA framework by users.
Chapter 5

The Methodological Framework Description

5.1. Framework Structure

The LADA methodological framework is underpinned by an integrative modular systems approach. The base entity for the application of the methodological framework is the country. It is envisaged that sub-national assessments would contribute to put together the national picture of the state of degradation. The sub-national assessments, whether at the Provincial or Major Basin level, could be built from assessments at the District or Watershed levels. These, in turn, will be built from the local (village or farm groups) assessment levels, which based on adequate and statistically-sound sampling schemes can be the basis for “upscaling” or “downscaling” to any regional or even global levels. Procedures for achieving these are also part of the framework. In this fashion the harmonization principle of the framework would be achieved.

5.2. The LADA Modular or “toolbox” structure.

In the LADA framework, methods, procedures and analytical tools are all compartmentalized into “modules”, which are oriented to achieving major tasks. This approach should bring enough flexibility, to fit the current availability of data in existent databases as to accommodate for the particular circumstances of the country, or country region, province, major basin, district, watershed or village where the framework is applied. The assessment team, assisted by decision support systems would take from the “toolbox” the methods, procedures and analytical tools required to achieve a particular task depending on the assessment scale (e.g. land cover analysis module, sampling module, livelihood analysis module, etc.). The tools and procedures can be selected from the corresponding compartment within the “toolbox” to fit the circumstances of the assessment. The modules in the toolbox consist of sets of procedures, which have been identified as being part of a main core of thematic or disciplinary procedures, integrated into a unit which performs a major task or set of tasks within the driving forces-pressures-states-impacts-responses paradigm. Each modular array performs a set of core tasks and takes input from and delivers output to other modules. Modules can be activated and used independently, but the final assessment may depend on the integration of results obtained from several modules. In that sense, the flows of data and information are all integrated. The emphasis on the framework structure is on bringing the necessary elements of data and information from the different capitals: i.e. the natural capital, the social capita, the human capital and the financial capital, which are the pillars of the livelihood systems, together for integration. These capitals translate into the integration of data and information from biophysical, socio-economic, cultural and demographic databases. These are all databases and information needed in the assessment process. The procedures for the assessment under the approach are based fundamentally on indicator variables and “proxies”. However, the framework would use any “hard” data provided by detailed measurements (e.g. sediment plot data), wherever they are available.
It is pertinent to state that the methodological framework does not have a specific flow of operations. There are multiple entry points to the assessment and there can be several partial information products derived from and during the assessment. Perhaps the most outstanding feature of the framework is that it allows the execution of land degradation assessment operations in such fashion as to permit that top-down operations (e.g. notably, operations based on remote sensing) and bottom-up operations (e.g. notably, field assessment procedures) to meet and results be harmonized. Therefore, one does not take precedence over the other, providing information products on the assessment at multiple scales. Detailed field assessment based on measurements, observations and indicator variables in the field are considered just as important in indicating land degradation at that given scale, as the changes of land cover that can be detected through satellite image interpretation at a much smaller scale. Their findings can be harmonized between top-down and bottom-up. Thus, the possibility of multiple entry points into the assessment.

Another important feature of the framework is that there is no specific sequence for operating the procedural modules. They can be used independently. While the framework structure is very inclusive, in order to conduct an assessment not all the modules need to be used, since the local circumstances of the country or region where it is applied will dictate what modules are relevant and needed.

5.3. The framework component tasks

The structure of the LADA framework consists of 12 major tasks or core sets of activities:

1. **Definition of area and scale**: Identify and delimit areas for the assessment and define the working and reporting scales.

2. **Select Indicators**: Identify (from the LADA list or LADA indicators DSS) the set of indicator variables relevant to the selected assessment scale. Include other local indicators and complement the indicators list as appropriate.

3. **Select methods, procedures and tools**: Select from the LADA toolbox the applicable thematic module(s) containing the methods, procedures and tools needed for the assessment at the selected scale, according to the indicators identified.

4. **Collect existing data and identify data gaps**: Gather and compile existent relevant data (spatial and attribute) and databases, (include satellite imagery, if applicable), identify data gaps and compare to LADA recommended minimum datasets.

5. **Stratify or partition variability**: Stratify variability (bio-physical, socio-economic) in the area into relevant units (zones, terrain/landscape units, land use, etc.) to be assessed. These will be the objects of assessment.

6. **Design a data collection strategy for missing data**: Design a data collection strategy consistent with data needed and in agreement with technology, local capacities and desired accuracy by:
   a. Designing a statistically-reliable sampling scheme on the basis of the strata or units and locate sampling sites based on the stratification.
b. Collect data in the field (if applicable) from designed sampling sites and surveys, for the relevant indicators and scale of the assessment.

7. **Analyze data**: Analyze data by applying the method and tools selected from the LADA-DPSIR framework “toolbox”.

8. **Integrate results**: Integrate results using the LADA decision support tool (whether the paper forms or digital decision-support system designed for this purpose) and establish causes, impacts and responses: Integrate findings and seek to establish causality, impacts on livelihoods, including the economic costs of degradation.

9. **Identify “hot spots” and “bright spots”**: From the integration of causes and responses to land degradation identify areas where degradation is being arrested and even reduced i.e. “bright spots and areas where degradation and degradation risk are high, i.e. “hot spots”.

10. **Validate results and assess accuracy**: Undertake implementing ground validation and verification of results, including finding and reporting uncertainties and assessment of accuracy.

11. **Map out and report results**: Map the spatial distribution of land degradation by designing a LADA-explicit legend (or by adopting the LADA legend suggested in the framework), and report findings.

12. **Monitor changes over time**: Design a monitoring strategy consistent with data availability and in agreement with technology, local capacities and desired accuracy.

5.4. The LADA 7-Step Approach and the LADA Framework 12-tasks

Distinction should be made here between the LADA approach and the LADA framework. As it has been noted in the definitions (Chapter 2), the 7 steps of the LADA approach refer to how to approximate or to set about implementing the LADA project. In contrast, the 12 tasks or sets of core activities part of the framework structure describe methodological and procedural options for executing a land degradation assessment according to the LADA approach. The relationship between the 7 steps of the LADA approach and the 12 suggested tasks or core set of activities in the framework as described in this document can be seen in table 1, below, and graphically in figure 5. It should be clear from table 1 and figure 5 that the 12 tasks of the framework are well comprehended within the 7-step approach and that the framework tasks provide more detail in terms of procedures and methods.

5.5. The LADA Framework 12 tasks and Decision Support Systems.

The LADA framework 12 tasks or core sets of activities rest upon the existence and proper function of decision support tools that connect the framework’s tasks to the database of indicators and the modules in the modular “toolbox” of methods and procedures. The decisions about what indicators and methods are pertinent to an assessment within a given context of given data and scale, both require of support. Decision support systems in LADA are closely linked to these tasks. The relationships
between the LADA framework 12 tasks and the decision support systems, including the toolbox of methods and tools, are illustrated in figure 6.

Table 1. Relationship between the LADA Approach Seven (7) and the LADA Framework twelve (12) tasks.

<table>
<thead>
<tr>
<th>Steps in the LADA Approach</th>
<th>LADA Framework Tasks or core set of activities</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Preparation of initial studies</td>
<td>1. Definition of area and scale</td>
</tr>
<tr>
<td>2. Establishment of a national LADA task force</td>
<td></td>
</tr>
<tr>
<td>3. Stocktaking and preliminary analysis</td>
<td>2. Select Indicators</td>
</tr>
<tr>
<td></td>
<td>3. Select methods, procedures and tools</td>
</tr>
<tr>
<td></td>
<td>4. Collect existing data and identify data gaps.</td>
</tr>
<tr>
<td>4. Developing a stratification and sampling strategy</td>
<td>5. Stratify or partition variability</td>
</tr>
<tr>
<td>5. Field survey and local assessments;</td>
<td>6. Design a data collection strategy for missing data</td>
</tr>
<tr>
<td>6. Development of a LADA decision-support tool</td>
<td>7. Analyse data</td>
</tr>
<tr>
<td></td>
<td>8. Integrate results</td>
</tr>
<tr>
<td></td>
<td>9. Identify “hot spots” and “bright spots”</td>
</tr>
<tr>
<td></td>
<td>10. Validate results and assess accuracy</td>
</tr>
<tr>
<td></td>
<td>11. Map out and report results</td>
</tr>
<tr>
<td>7. Development of a LADA monitoring tool</td>
<td>12. Monitor changes over time</td>
</tr>
</tbody>
</table>

Figure 5. Relationships between the LADA 7-Step Approach and the LADA Framework 12-Tasks or core set of activities
1. Definition of area and scale

2. Selection of Indicators

3. Selection of methods and tools

4. Collection of existing data and identification of data gaps

5. Stratification of variability

6. Design of a data collection strategy

7. Data Analysis

8. Integrate results

9. Identify “hot spots” and “bright spots”

10. Validate results and assess accuracy

11. Map out and report results

LADA Indicators Decision Support System

LADA Framework Modules or “Toolbox”

Visual Field Assessment Tool

Indicator Processing Engine or tool (Combines Indicators)

Causality Engine or tool

Fig 6. CORE SET of ACTIVITIES OF THE LADA METHODOLOGICAL FRAMEWORK and their relation to DECISION SUPPORT TOOLS
The decision-support systems envisaged as essential in the LADA framework and illustrated in figure 6, above, should provide support to the LADA teams in order to arrive at important methodological and implementation decisions. The systems provide information and answers to fundamental user questions. Some of the most critical questions are as follows:

- What is the appropriate set of indicators at the selected scale for an assessment?
- How are these indicators estimated/measured/observed?
- How are the values or categories of these multiple indicators combined?
- How are all kinds of factors and indicators integrated into an assessment?
- How is causality (i.e. driving forces and pressures) determined?
- How are the nature, extent, severity and impacts of land degradation reported into a single standard characterization or legend?

The answers to such kind of questions can be related to the necessary decision-support systems, toolbox and databases part of the LADA framework. Figure 7 illustrates the relationships between these essential questions and the LADA decision-support systems and tools.

Figure 7. Support provided by LADA decision-support systems, databases and tools to answer fundamental questions by users in the implementation of an assessment.
The presence of decision support systems is fundamental to the selection of indicators, methods and tools for their measurement, analysis and integration into a given characterization scheme or mapping legend. The modular structure of the framework could not function without these decision support systems. The modular toolbox of methods and procedures and the database of indicators provide the substantive content, which is accessed and obtained through the decision support systems. Typically, a user after fixing the scale of the assessment will need the decision support systems to determine and access relevant indicators, the methods and procedures for their measurement or estimation and thenceforth for their analysis, combination and integration into an characterization protocol or assessment legend.

5.6. Scale in the LADA Framework as related to Decision-Support Systems, Methods and Tools.

The LADA Framework considers the differences that exist between the variables indicators of land degradation at different scales of the assessment. Spatial and temporal scales are very important factors in the choice of indicators and therefore in the results of the assessment. It is clear that the indicators that provide evidence of the state of degradation at one scale (e.g. vegetation cover changes as detected from satellite imagery at a small scale) may not operate at another scale (e.g. soil sheet erosion at farm plot scale as evidenced by exposure of tree and shrub roots). Dependence on scale in decision-making concerning indicators, and therefore methods and tools for their measurement and analysis, forces scale to be a necessary entry point in any assessment. The determination of what is the scale desired for the assessment is an independent decision, usually made by the assessing team and often responding to policy priorities and seldom to technical considerations. Fixing the assessment scale reduces considerably the range of possibilities in the choice of indicators and analytical tools therefore focusing the assessment on only the relevant indicators, methods and tools that achieve meaningful results at the chosen scale.

To each scale, ranging from the global, national, regional or major basin, district or watershed, local or farm level, corresponds a set of relevant indicators and a set of methods, procedures and tools to measure, estimate or observe, and analyse the relevant indicators. The proposed LADA decision-support systems and tools should provide answers to such scale-dependent decisions. The relationship between scale and decision-support systems in LADA is illustrated in the diagram shown in figure 8.

5.7. How to use the LADA framework

The use of the LADA framework requires, first, following the LADA 7-step approach. The 12 tasks in the framework are in sequence (table 1 and figure 5) and harmonized to the 7-step approach (Koohafkan et al, 2003). Along the progressive sequence of the steps the framework’s 12 tasks (section 5.3) provide greater detail on sequence of activities. These activities are assisted by the decision support systems (figure 6). Thus, the LADA framework should be used as a modular or compartmentalised toolbox of methods,
procedures and tools, whose access and use are assisted by the decision support systems part of the framework.

So, depending on the situation of data, expertise and scale for the assessment, users must use of the decision support systems to obtain guidance as to indicators, methods and procedures and then analysis, integration and report of findings. The scale must be chosen first, then the corresponding set of indicators that are suggested (i.e. from the Indicator Decision Support System; figures 6 and 7) as being relevant to the scale, data and other circumstances of the assessment. Once the set of relevant indicators is chosen, the selection of the required methods, procedures and tools for their measurement, estimation, observation and/or modelling is carried out, assisted by the LADA Methods and Tools Decision Support System. Once the selection of methods, procedures and tools is finalized, the modular “Toolbox” is accessed and methods and tools retrieved for their application to data. The LADA framework modular toolbox is compartmentalised into modules or sections from which specific methods and tools can be accessed and specific methodological description obtained. It must be noted that an important component of the “toolbox” for local assessments is the Visual Field Assessment Tool (figure 8). The framework’s toolbox, as depicted in figures 6, 7 and 8, is illustrated in terms of its modular components in more detail in figure 9. A more detailed and descriptive view of what are the elements in each of the modules or compartments of the “toolbox” is illustrated in figure 10.

The decomposition of the basic over-generalized modules illustrated in figures 9 and 10 and part of the framework’s “toolbox” into its individual component modules and their respective sets of analytical operations, is at the core of methodological framework design. The details of each method, procedure and tool within each of the modular components are substantial and far too large to be provided here. They can be consulted separately in Annexe “B” to this report. The complete methodological framework “toolbox” is depicted in the form of a flowchart and included as Annexe “A” to this report. The modular components (represented by hexagonal shapes), the connections between them and between them and the databases (cylinder shapes) and between the modules and external operations (oval shapes) and between all and the resulting information products or outcomes of a modular procedure (rectangular shapes) are charted as analytical paths. More detailed discussion of such modular components is provided in Annexe “B”. In a given geographical area of the world, the assessment can begin with a set of preparatory operations ahead of field activity. These preparatory operations start with some data. There are thematic data already present to a various degrees of completeness, accuracy, scales and lineage in any part of the world. These databases represent the starting point to the set of preparatory operations prior to the assessment. Also, international agencies with global mandates have already collected data at a variety of grains and resolutions as illustrated in Annexe “A”.

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Figure 8. Scale-dependent decision support on indicators of land degradation and the methods, procedures and tools appropriate to the selected scale.
Fig. 9. THE MODULES OR “TOOLBOX” OF METHODS, PROCEDURES AND TOOLS

- CLIMATE ANALYSIS MODULE
- REGIONALIZATION & UPSCALING, DOWNSCALING MODULE
- DEMOGRAPHIC ANALYSIS MODULE
- FARMING SYSTEMS/ LIVELIHOODS MODULE
- ECONOMIC ANALYSIS MODULE
- PARTICIPATORY FIELD ASSESSMENT MODULE (DSS)
- METHODS & TOOLS SELECTION (DSS)
- INTEGRATION & SYNTHESIS MODULE (DSS)
- INDICATORS MODULE (DSS)
- DSS
- SAMPLING SCHEME MODULE
- PROCESS MODELLING MODULE
- ZONING & STRATIFICATION MODULE
- REMOTE SENSING & LAND COVER MONITORING MODULE
- NATURAL RESOURCES DB
- NR USE, SOCIO-ECONOMIC DB
- LADA USER ACCESS
Fig. 10. A more descriptive view of the MODULAR “TOOLBOX” of methods, procedures and tools
5.8. The LADA Decision Support Systems

The framework envisages the presence of three main decision support systems. Namely:

- Indicators Decision Support System
- Methods and Tools Decision Support System
- Integration Decision Support System

These are described briefly in the following sections.

5.8.1. LADA Indicators Decision Support System (IDSS)

The indicators decision support system (IDSS- figs 6, 7 and 8) should provide users with support on decisions concerning the selection of appropriate indicators relevant to the spatial scale and the technical, procedural and local conditions, available technology, knowledge and cultural circumstances of the assessment. The IDSS should also suggest the set of relevant indicators as well as units and scale of their measurement/observation. In addition, the IDSS should have the following characteristics:

- Be of global scope in the sense of providing indicators for all dryland conditions in the world.
- Wholistic in the sense of encompassing all past, present and new indicators of land degradation proposed from all variety of entities, and account for all the elements in the DPSIR approach.
- Recursive in the sense of eliciting user input of national, regional or local indicators not yet included.
- Flexible in the sense of being amenable to be adapted to user needs, technology, data availability and technical background of users.

Efforts to develop such IDSS are already underway at FAO (e.g. Matranga and Bunning, 2004 –unpublished). An illustration of the prototype under development is shown in figures 11 and 12 below. The IDSS is supported by a fairly comprehensive indicators database (figures 6, 7 and 8).

Concerning indicators, the following are noted as possible considerations that come to bear on the development of the IDSS. First, LADA should define a minimum set of indicators for an assessment to warrant consistency and comparability between assessments. The minimum indicator set is to be embedded in the IDSS. Second, criteria for the selection of the minimum indicator set should be made in consultations with the regional stakeholders of each dryland condition in the world. Third, the LADA process should also decide the extent to which is to rely on indicator sets developed in other specialized agencies. Finally, LADA should envisage its role as an “indicators warehouse” to fully support the work of assessment entities at any scale all around the globe.
Figure 11. A prototype of a Land Degradation Indicators Decision Support System (Matranga and Bunning -unpublished-)
Figure 12. Access and Reporting capabilities of the Prototype Indicators Decision Support System for land degradation assessment (Matranga and Bunning, 2004 –unpublished-)
5.8.2. Methods and Tools Decision Support System (MTDSS)

Assessors of land degradation will also require support on their decisions as to the selection and use of the appropriate methods, procedures and tools for the measurement, observation and recording of the selected indicators at a given scale. They will also will require support for their analysis and processing in order to arrive to a dryland condition assessment. The methods and tools decision support system (MTDSS) is designed to provide that support. A highly interactive graphic user interface (GUI), such as that illustrated in figure 11, should enable users to access the “toolbox” (illustrated in figures 8, 9 and 10). Currently, there are no existing prototypes of this MTDSS but one is being a subject of research and its development has started at the GISLR lab at Trent University.

The “toolbox” has been described above in section 5.6 and illustrated in figures 9 and 10. The complete “toolbox” accessed through the MTDSS and all procedures within it are described at length in Annexes A and B to this report.

5.8.2.1 Visual Field Assessment Tool (VFAT)

It is worth noting that the visual field assessment tool could become extremely useful in local LADA assessments and that in its current version, it is already operational on paper format. Guidelines exit (Stagnari et al, 2004), and also case examples of their application to vineyards and olives, and to other crops in other parts of the world. Automation and web access of this tool could be very valuable in supporting assessments at local scale and in drawing comparisons. An automated VFAT linked through the MTDSS could provide, in parallel to the “toolbox” an alternative to local assessments where conditions of data scarcity and technology availability limitations warrant its use.

5.8.3. LADA Integration Decision Support System (IntDSS)

Once indicators are selected with help from the Indicators Decision Support Tool (IDSS) (section 5.8.1. above) and the selection of the methods and tools for their measurement and processing and analysis supported by the Methods and Tools Decision Support System (MTDSS) linked to the “toolbox” there is still a pending problem, that of the integration of results into an assessment. Since numerous indicators can be used at any given time during the assessment, user support will still be required to enable the consistent, comparable and replicable integration of the status of the indicators into an assessment meaningful for policy formulation. It is arguable whether this integration should also be part of the IDSS. However, to avoid oversimplification of a rather intricate process it is suggested that such integration is carried out in a dedicated Integration Decision Support System (IntDSS). This system has two main components:

- Indicator Processing Engine or Tool (IPE)
- The Causality Engine or Tool (CausE)

This is clearly illustrated in figures 6, 7 and 8 above.
5.8.3.1. Indicator Processing Engine (IPE)

This tool is to be linked to the IntDSS and should provide a highly interactive support to users in selecting the method by which indicator data already measured and obtained should be combined. There are a variety of forms for indicator combination. Namely:

- **Using weighting methods** to assign “weights” to individual indicators according to either, prescribed sets of weights by the system or user-suggested weights, making the process more participatory. Examples of this type of IntDSS is the prototype designed by the “Desertlinks” project: [http://www.kcl.ac.uk/kis/schools/hums/geog/desertlinks/](http://www.kcl.ac.uk/kis/schools/hums/geog/desertlinks/).

- **Using decision-trees** to assign both priority and importance to individual indicators and their ranges of values in order to arrive to a final assessment. There are no many examples of the use of decision-trees, other than in land suitability assessment (e.g. the ALES approach described in Rositter, 1986). However, Figueroa-Cano (2000) and Figueroa-Cano and Ponce-Hernandez (2000) and showed how indicators can be coded into a decision-tree for assessing “sustainability”. This approach allows for the consideration of both, biophysical and socio-economic indicators measured at both, the ratio, interval and nominal scales. An example is illustrated in figure 13. It must also be mentioned that there is widespread knowledge of decision-trees as a useful tool for land evaluation in many parts of the developing world and that its adoption for degradation assessment should not represent a technological barrier to overcome.

- Using more sophisticated methods such as Artificial Neural Networks to combine the attributes of indicators (e.g. Callejas-Saenz and Ponce-Hernandez, 2001). These, due to their complexity and degree of reliance on high technology are deemed not suitable for being part of the IPE.

5.8.3.2. Causality Engine or Tool (CausE)

The causality engine or tool is linked to the integration decision support system (IntDSS) in order to provide support, once the indicators have been combined into an assessment (section 5.83.1. above), on the finding of the causal factors of degradation. Since the LADA methodological development is predicated on the DPSIR approach and on the finding and characterizing land degradation states and their causes, finding causality becomes paramount to the results of the assessment.

Establishing causality between the states of physical, chemical and biological land degradation and the driving forces and pressures causing them cannot be a deterministic approach since there are far too many factors at play as possible causes and their effect on final state of degradation is either, not yet completely understood or it changes with the socio-political, cultural and economic contexts. Therefore, there will always be a probabilistic element in ascertaining the causality of a degradation state, regardless of the assessment scale.
Figure 13. Coding of bio-physical and socio-economic indicators together into decision-trees in the ALES program (after Figueroa, 2000)
Two approaches to establishing causality can be part of the causality engine or tool, which in turn is part of the Integration Decision Support System (IntDSS). These approaches are:

- Analogue or “manual” approach (i.e. paper forms) based on expert knowledge.
- Automated approach based on a digital causality engine or tool based on networks of causal chains (NCC), which could be accessed via web.

Both approaches are discussed in more detail below.

**Manual or Analogue Approach to finding causality**

Finding causality under this approach entails a manual procedure with the creation of “fill-in” paper forms that include a comprehensive list of indicators of driving forces and pressures. From these a local expert or a knowledgeable assessor of the geographic area chooses the indicators that are considered relevant and writes them down on the blank space to the right of the form. This is done for each of driving forces and pressure indicators. Then, the local expert connects driving forces to pressures by drawing by hand on the same paper forms connecting arrows that link the indicators selected from the lists. These indicators were observed/measured or data on their status are available. The pressures are linked in the same fashion to the indicators of the state of land degradation, according to the expert’s own experience and knowledge of the geographic area where the assessment is being performed, and supported by data from interviews, documented evidence in reports and other available information. The manual or analogue form to establishing causality through local expert judgement is illustrated in the diagram of figure 14. The requirements for the implementation of this method at the local level are minimal. They consist of a series of pre-formatted, fill-in paper forms and the identification of an experienced local expert. The forms should contain knowledge in the form of a comprehensive list of indicators of driving forces and pressures and of the measured states of degradation.

**Automated Approach to finding causality through Networks of Causal Chains (NCC) built in the Causality Engine (CausE)**

Networks of Causal Chains (NCC) have been used successfully in a variety of ecological instances to determine the possible and probable causes of a given state of a system (e.g. Pearl, 2000; Cloern, 2001; Borsuk et al, 2001a, 2002a and 2003; Weidl et al, 2003). Such networks are constructed on Bayesian theory. Bayesian networks for causal analysis may seem complex for the unaccustomed reader. However they are commonplace in many other disciplines where causality and probability of causality are to be found.

The Causality Engine (CausE) or Tool is to be based on Bayesian Networks of Causal Chains (NCC). A prototype of NCC is to be under development soon at Trent University to contribute to the LADA process.
The Bayesian networks of causal chains are to be built in a highly interactive way by the user of the CausE tool. The causal engine (CausE) will have built in the algorithms for allowing the user graphically and interactively calculating the linkages and establishing the networks of chains of causality linking driving forces to pressures and onto states of land degradation. An example of the NCC is illustrated in figure 15. In this example the links represent autonomous mechanisms as described by probability functions. Each set of arrows pointing to a giving node \( X_i \) represents a function of the form:

\[
X_i = f_i(p_{a_i}, \xi_i)
\]

Where \( p_{a_i} \) are the parents of the node \( X_i \); \( f_i \) are the probability functions and \( \xi_i \) are independent random disturbances. The outcome of the process in the Causal Engine using the NCC is the Bayesian or “Markov Blanket” of causistic variables or “strongly relevant causistic variables”.

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**Figure 14** Manual or Analogue method for finding causality through linking driving forces and pressure indicators to states by drawing causal arrows (in red colour) by experienced local experts in the geographic area of the assessment. The approach employs paper forms and lists of relevant indicators selected by the expert in the fill-in space to the right of the list.

- **Indicators for Driving Forces**
  - Check List
  - Fill-in by Local Expert/Farmer/Land manager

- **Indicators for Pressures**
  - Check List
  - Fill-in by Local Expert/Farmer/Land Manager

- **States of Degradation**
  - Soil erosion (rills)
  - Soil erosion (gully)
  - SOM depletion
  - Salinization
  - Loss of soil habitat
  - Fertility decline and loss of productive capacity
  - Soil biodiversity decline

Blue arrow implies a selection by the local expert of the relevant indicators from the comprehensive checklist to the left of the form and their writing on the fill-in blank space in the right of the form.
Figure 15. Networks of Causal Chains (NCC) resulting in the states (S) of land degradation highly likely caused by the pressures (P) and the driving forces (D). The example illustrates the workings of the Causality Engine (CausE) in establishing through Bayesian networks the causality of P and D (these are known as the “Markov Blanket” of causistic variables or “strongly relevant causistic variables”)

A very illustrative example of the application of the causal chains approach to land degradation assessment at local scale was given in the report by Rebecca Dixon (2003), working in two different dryland conditions in Mexico. In that work the causal chains were obtained manually from local expert consultation via interviews and the application of field questionnaires. The results of this exercise are illustrated with an example of a causal chain in a natural capital, the driving force is the demands for primary productivity of the land resulting in a variety of related pressures, notably, the recess of land cover with the resulting exposure to soil erosive forces. A variety of degradation states result from such pressures as illustrated in figure 16.
Figure 16. Example of a selected Causal Chain in the natural capital. Driving Force is demands for primary productivity, related Pressures e.g. recess of land cover/exposure to erosive forces with corresponding resulting states of degradation and impacts in “El Alegre”, San Luis Potosi, Mexico (after Dixon, 2003).
The work of Dixon (2003) in Mexico also illustrate how the same “causal chains” procedure can be applied to established the impacts that the different states of land degradation could have on peoples’ livelihoods and the responses generated by farmers and land users to such impacts.

5.8.4. A GeoWeb System for LADA

An effective mechanism for information dissemination about any of the aspects of the DPSIR indicators of a given geographical area and their dependence on the spatial scale, is fundamental to help decision and policy makers visualize the problems of land degradation and their impacts on people’s livelihoods. The strong dependence on scale of the indicators of both causes and states of degradation can be portrayed dynamically through a set of sequentially harmonized georeferenced images of jurisdictions at multiple scales, from the smallest possible (in the geographical sense) to the largest possible. The display of such imagery together with the status of corresponding indicators of causes and states in a given geographic area conveys a powerful and informative message. This type of information can be made accessible to users via the internet, provided the imagery is available and the results of the LADA assessment for the given country and jurisdictions are available. This type of information and decision support system would integrate visually the results of assessments, with the added advantage of allowing for the inclusion of photographic material and other multimedia sources (e.g. film streams, voice, etc.). The result is a GeoWeb system for LADA.

At present, the LADA GeoWeb is at the conceptual and early development stages and it is to be illustrated with a case study in a given country for which there are both, multi-scale images and results from assessments. Figure 17 illustrate the concept of the LADA GeoWeb.
Figure 17. Illustration of the multi-scale LADA GeoWeb. At each scale the indicators of the state of land degradation and causes will be displayed.
Chapter 6

Conclusions and Recommendations

The element components and the architecture of a methodological framework for LADA have been outlined and briefly described in their simplified version in this document. The correspondence between the LADA 7-step approach (Koohafkan et al, 2003) and the proposed 12 tasks or core sets of activities have been established and charted. A key element of the methodological framework is the scale of the assessment. Once the scale is fixed, all the other elements necessary for the assessment, i.e. indicators, methods and procedures for their measurement and analysis, including sampling schemes, the integration of results and the establishment of causality can also be determined. The framework is reliant on the presence of decision support systems to assist users in the selections of indicators, methods, tools and with their analysis and integration into an assessment. The fine details of the methods and procedures in the so-called “toolbox”, are of extreme importance in providing guidance to assessors and users. However that substantial bulk of information can only be provided as annexes.

Several innovative elements are introduced in the framework: first, the framework relies heavily on the presence of decision support systems, which conceivable could be implemented on the internet as web-based systems. It is deemed fundamental that work on the development of these decision support systems continues and reaches successful completion, and that their development and testing is achieved in consultation with stakeholders. Second, the procedures for integrating the multiple values of indicators into an assessment have the potential of making an important contribution in the field while being of practical use. Moreover, the methods and procedures suggested for finding causality are also innovative and require extensive development. At this stage these elements can be taken as “proof of concept” until prototypes are developed and tested in case studies. It is highly recommended that work on all decision support systems, including the methods and tools decision support system and its “toolbox”, the visual field assessment tool, the indicators decision support tool, the integration decision support system with the tool for combining indicators and the causality engine or tool, continues and achieves the prototype stage for testing on data from case studies in the field. The LADA GeoWeb concept should be further developed and implemented from proof of concept into a prototype for possible testing in areas where there are sufficient image data and assessments.
Chapter 7

References


FAO (2002) LADA Workshop Report, Land and Water Development Division, FAO, Rome

FAO (2003) Land Degradation Indicators. World Soil Resources Reports # 100. FAO, Rome.


