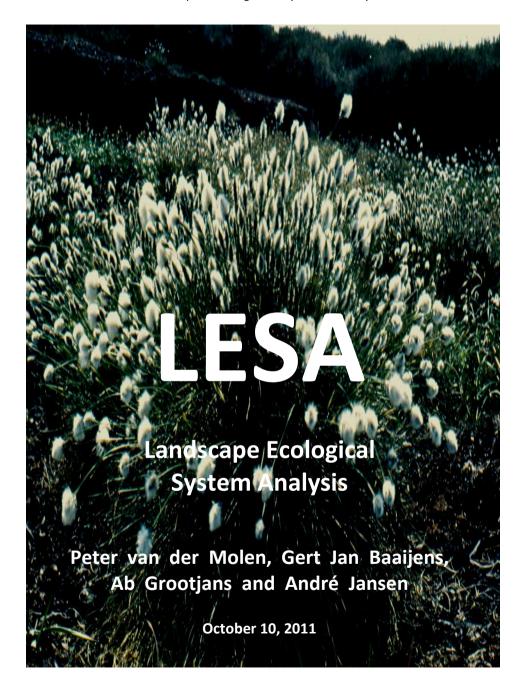


- Landscape Ecological System Analysis -



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Colophon

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- Landscape Ecological System Analysis -

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PREFACE

The 'Landscape Ecological System Analysis' is the anchor of any management- or spatial plan. It is a comprehensive description of how the landscape in the study-area evolved, how it functions and which processes determine the presence and distribution of flora, vegetation and fauna. This understanding is the basis for long-term management and planning for an area.

During such an analysis, it is essential to follow a sound and verifiable procedure, to be thorough and to be able to indicate when the analysis can be concluded confidently. A 'Landscape Ecological System Analysis' starts as a desk-study, with a broad perspective and gradually zooms in and focuses on the area involved and identifies relevant and verifiable questions and their priority. Step two is the actual field analysis, after which one returns to the desk in Step three, for analysis of the field data and synthesis. During this procedure one continuously develops and tests verifiable hypotheses concerning the functioning of the area.

So one zooms in on the area and then zooms out again, this iterative process eventually leads to an understanding of the functioning of the ecological system of the area as a whole, while simultaneously providing an overview of gaps in knowledge and information. It is important to keep the extent and depth of the analysis in mind, as well as in time and space. The extend and duration of the analysis should be tailored to the area and the questions involved.

Ultimately, a management plan provides the framework for conservation and restoration measures for a certain period of time. The choices made rest on the foundation laid by the *'Landscape Ecological System Analysis'*, which therefore needs to be executed transparently and responsibly.

Central to drafting a management or development plan is performing a 'Landscape Ecological System Analysis' or LESA. The words 'Landscape Ecological' indicates a description of the relationships between species and/or habitat-types with their environment. This is necessary in order to determine -first of all- the effects of the current use of the area, on the

existing and potential natural values; and second which measures are necessary to keep or bring them into a favourable conservation status or to realise other conservation goals, both in space and time.

Practically speaking – the analysis for habitat-types focuses primarily on site conditions, and relates them to the processes that determine the environmental conditions on a landscape scale. It also includes the effects of human influence on these processes and conditions. For species, the analysis focuses mainly on the range, size and quality of their habitats and the processes that determine these.

In order to understand the landscape, one has to have an open eye and mind for all that can be observed in the field. Landscape is defined by the German philosopher Rosenkrantz (1850)¹ as the "stufenweise integrierte Lokalsysteme von Faktoren aller Naturreiche", or the stepwise integration of local systems of all realms of nature – so this includes human and animal activities. Unfortunately fauna aspects often suffer from a lack of attention and appreciation, so most of the time they are not included in the landscape ecological analyses.

This definition of landscape also implies that we should not limit ourselves to what we consider to be 'nature', but that we also need to include the use made of the landscape by man. For example infrastructure or (historical) agricultural use. Farmers, with their spades, have always been masters in 'applied ecology'. By reconstructing the principles behind their use of the land, we can deduce the original ecological processes and gain insight on the landscape as a system.

For a landscape ecological analysis, one needs an integrated knowledge of geology and geomorphology, soil science, hydrology, vegetation science (including the meaning of indicator species) and historical land use. Furthermore, one needs a healthy scepticism regarding the limitations and certainties of all these disciplines. In all of this, plants, the language of the field, have proven to be the most reliable witnesses for the understanding of the landscape and hold a higher authority than maps, written sources or

34.

¹ Cited by Schmithüsen, J. (1968): Der wissenschaftliche Landschaftsbegriff. In: R. Tüxen (red.): Pflanzensoziologie und Landschaftsökologie. Bericht. über das 7. internationale Symposium in Stolzenau/Weser 1963 der Intern. Ver. für Vegetationskunde. Den Haag., p.23-

computer-models. Through their absence and presence, they indicate whether or not their environmental requirements are met. The many studies on this particular topic are therefore a crucial tool for the landscape ecologist.

This manual is the result of the contributions of several people² and explains the procedure for performing a 'Landscape Ecological System Analysis' and supplies some rules-of-thumb.

- 2

² This document is based upon:

DLG / SBB werkkader Beheerplannen - bestaand gebruiks. (P.C. van der Molen, C.Y. Weebers en C.J.S. Aggenbach; 2007).

Landschapsecologische Systeemanalyse bij de beknopte gebiedsanalysen van: Gieten, Dwingelerveld, Haaksbergerveen en Groote Heide. (G.J. Baaijens, A. P. Grootjans en P.C. van der Molen, met medewerking van E. Kiestra en A. Lanting; 2011).

De vegetatieontwikkeling van beekdalsystemen; een landschapsecologische studie van enkele Drentse beekdalen. (F.H. Everts en N.P.J. de Vries; 1991).

Project Zien door monitoren. Stappenplan gebiedsanalyse toegepast in de Casebeschrijvingen Het Ham en Dommelbeemden. In opdracht van PTC+, HAS Den Bosch en AOC Limburg. (J.L.J. Hendriks; 2005).

Contributions by: members of the OBN-Deskundigenteam Nat Zandlandschap as well as the Programma Directie Natura 2000 of the Ministry of EL&I

1. LANDSCAPE COMPONENTS

Central to landscape ecology are the connections between the various landscape components such as climate and geo(morpho)logy, water, soil, flora, fauna and mankind. Each of these component provides a framework for the next. So in this sense every next and smaller layer is dependent on the previous, larger one, but also influences and changes that previous one. This order provides the basis for the stepwise landscape ecological approach. It also helps to reconstruct how the landscape functioned before human interference, which helps to assess the magnitude of this later influence.

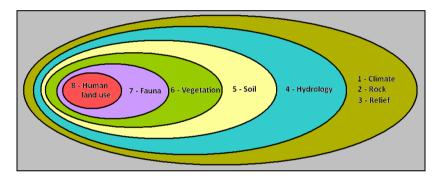


Figure 1 The various landscape components and their mutual relationships. (adapted from: Schroevers, 1982³).

In a 'Landscape Ecological System Analysis', one always considers the presence of material aspects (air, soil, water and biomass), their distribution in the study-area (pattern, spatial arrangements) and their inter-relationships (processes). These presences, distributions and processes taken together, determine the structure of the landscape, the patterns found and the changes over time. After the 19th Century, human influence has increase in scale and impact, to such a degree that human influence is now noticeable on a global level. On more local levels, human influence has usually become the most dominating factor.

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³ adapted from: P.J. Schroevers (red.) (1982): Landschapstaal. Een stelsel van basisbegrippen voor de landschapsecologie. Wageningen



LEVEL 1, 2 and 3 Climate, rock, relief

Geological information on the stratigraphy of the deeper layers of the earth's crust, and the description of the landforms at the surface is important, for it is the basis for all processes on the surface. Geological landforms are generally distinguished on the basis of the origin of their sediments, classified as formations, and their structure and dynamics, such as tectonics or volcanism. Stratigraphical information can show us layers with an unusual structure or composition, which can for example influence the hydrology. Geological maps are therefore an important source of information, but one always needs to establish the link between the surface patterns and the stratigraphy of an area. Geological information is only useful when considered in three dimensions.

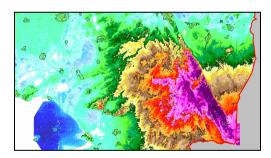


Figure 2: Relief map of the Province of Drenthe (The Netherlands)

The surface morphology is determined by geological factors such as composition of the sediments or bedrock, but also through processes such as sedimentation and erosion or through geological processes and in the higher latitudes also by glaciations. Geomorphological maps are often useful to see the most relevant landforms, however, the recent availability of digital terrain maps provides truly useful information on the geographic relief, for it is unbiased and generally not limited to the study-area.

Geographic Information Systems are an indispensable tool for these analyses.



Level 4 - Hydrology

Water is often one of the most determining factors in shaping the patterns in the landscape. In mountainous areas, water erodes rock, which deposits further down the slopes and river systems in the form of gravel and sand. These areas usually show marked differences in drainage, through retention, infiltration or the opposite: seepage of water. This gives rise to very different environmental conditions, ranging from dry pastures to raised bogs. Along rivers we find a variety of landforms, ranging from flood-plains with active meanders in the main channel, to totally cut-off oxbow lakes. Further down to the mouth of the river system, one finds coastal systems with an increased influence of salt water and finally intertidal flats and dunes and one shifts from sandy to clay deposits. In some areas, land lies below sea-level and is just protected through dikes and levees, and the presence of water from both rivers and the sea is felt even more strongly. On certain locations we have very special groundwater conditions such as stagnation or false ground-water levels above the regular freatic ground-water level due to impenetrable layers in the soil caused by for example iron pans or humic bands.

In landscapes water quantity as well as quality are crucial factors, for they determine many other processes. Water quantity is the amount of water moving through a landscape, both above or below ground. Analysis of the water regime, using hydrological modelling of ground and surface waters, is employed to establish a water balance for an area. This is necessary to determine if habitat conditions of species or vegetations are met, or can be met, through water management measures. It is often found that during these analyses, density differences are ignored, except when dealing with

salt or brackish waters. However, one has to bear in mind that also in sandy soils density differences can be an important factor.

Water quality is another determining factor. With water quality we not only mean pollution of water, but primarily the chemical composition of water types. What substances are dissolved in the water, is it acidic or rather alkaline, what is the salinity, is it rain water or old groundwater welling up through seepage? Several of these factors can to some degree be determined in the field using pH and electrical conductivity meters, which provide the first clues towards an understanding of the processes taking place in the study-area. Others need to be established using water samples and laboratory analyses.



Figure 3: Hydrological studies: dip-wells and piezometers in a bog.

The combination of water quantity and -quality usually determines the nature values in an area. Therefore in landscape ecological research these are always studied simultaneously. For example when monitoring-wells or piezometers, are placed one can combine this with other observations. Monitoring-wells are often smaller diameter wells to measure the hydraulic head over defined discrete sections of an aquifer. Often several monitoring-wells are placed in stations on a location, to allow for discrete

readings at different depths in the aquifer. One can of course also use them for sampling groundwater for chemical analyses of different groundwater layers. During placement, one should also analyse the soil material that is extracted during the coring, to obtain (sub)soil profiles. Placing these stations in transects across parts of the study-area, enables one to connect the results on water quantity and flow, water chemistry and subsoil composition and stratigraphy, with observations on flora, vegetation and fauna on the surface. This yields an integral picture of that part of the landscape ecological system.



Level 5 – Soil and recent land use

Under the influence of atmosphere, parent material, water, vegetation and use by man, different soil types are formed. The soil that we find in our study-area at the present time, is the sum of this range of pedogenic processes that have been active over centuries; although it is difficult to see these processes at work nowadays or to quantify them. In order to understand soil genesis and even to predict the future developments of a particular soil type, one needs a good grasp of the processes that have led to their formation. The position of these soil types show us how these factors interacted in a particular landscape and are therefore essential in understanding the system.

Characteristics of soils and soil-landscapes, such as the number, sizes, shapes and arrangements of soil-bodies, can be observed and measured, since they can be characterized on the basis of soil-horizons, degree of internal homogeneity, slope, aspect, landscape position, age and other chemical and structural properties and relationships. Soil-sampling using augers or even drilling, is used to gain an accurate insight into the distribution of these soil-types. The results are used to find correspondences with evidence of recent changes in environmental conditions such as changes in the groundwater levels or pollutions. This is

particularly the case in former industrial or agricultural environments. For example in the case of the latter one can find overloads of fertilizers as phosphate.

Soil-chemistry is an important factor determining the vegetation and fauna living on its surface, especially the degree of acidity or alkalinity (pH) or the redox-potential. The pH of a soil is dependent on the kinds of parent materials from which the soil was formed. Soils developed from more alkaline rocks such as limestone generally display higher pH values than those formed from acid rocks such as granite. Rainfall also affects soil pH. Water passing through the soil leaches alkaline nutrients such as Ca and Mg from the soil. They are replaced by acidic elements such as Al and Fe. For this reason, soils formed under high rainfall conditions are more acidic than those formed under arid conditions. Soil acidification may also occur due to decomposition of organic matter, acid-forming fertilizers, and exchange of alkaline cations for H⁺ by roots. Soil acidity is reduced by processes like evaporation of water and denitrification. Under flooded conditions, the soil pH-value increases. Several nitrate fertilizers such as calcium-, magnesium-, potassium- and sodium-nitrates also increase the alkalinity of the soil. These factors plus aeration, affect the redox-potential of soils, which in turn strongly determine the chemical composition of the soil.



Figure 4: Fieldwork soil mapping.

The redox-potential provides an indication of the way in which chemical reactions will proceed in oxygen deficient soils and this variable controls the nutrient cycling in flooded systems. Redox-potential, or reduction potential, is used to express the likelihood of an environment to receive electrons and therefore become reduced. For example, electron rich systems will be reduced and donate electrons to a part of the system that has a low concentration of electrons, or an oxidized environment, to equilibrate to the chemical gradient. The oxidized environment has a high redox-potential, whereas the reduced environment has a low redox-potential. The redox-potential is controlled by the oxidation state of the chemical types, pH and the amount of oxygen in the soil.

In addition to these chemical factors are biological factors: soil life in the form of small soil fauna such as nematodes and also fungi and microbes are increasingly recognized as essential but undervalued components of the soil system.



Level 6 - Vegetation

Plants respond to the combination of soil-factors, water and climate taking into account the chance that their diaspores can arrive there. Since plants often have specific ecological requirements as well as tolerances, more or less distinguishable groups or vegetations will develop. Vegetation mapping, using so called relevés is used to provide an indication of the distribution of so called vegetation-types in an area. Relevés are small plots where all plant species are recorded and their contributions to the total coverage of that plot are estimated. Computer programs such as TURBOVEG are then employed to enter these relevés into a data-base that can then be used by computer programs such as ASSOCIA to classify the results into standard vegetation-types. In this way the local map can be translated to an international system of vegetation-types.

These data can be compared using a tool such as SynBioSys⁴. The species composition can be compared with relevés from previous surveys or similar sites and this will contribute to an understanding of the current site conditions. Have they changed and, if so, how? Is this a result of environmental changes such as dropping groundwater levels or has the vegetation changed due to natural succession or under the influence of management.

It is also possible to map particular plant species that are indicative of special conditions such as seepage, acidity/alkalinity, soil disturbance or for example the occurrence of metals such as zinc. These plants are very specific in their preference for certain habitats and normally occur in very narrowly defined ranges of environmental conditions.



Level 7 - Fauna

Fauna is usually responding to given (a)biotical conditions and is strongly under the influence of vegetations structure and composition and connectivity. However, animals also determine these vegetation patterns, for example through grazing. In the landscape ecological analysis, animals often play a secondary role, but it is very useful to examine the occurrence of species in the study-area and their habitat requirements.

Lately much has become clear of the importance of landscapeheterogeneity for animals. Many animals use the landscape in a flexible manner for various stages of their life-cycle. They switch for example from one food source to another, depending on supply, or they use different habitats for foraging, resting or breeding.

⁴ See: http://www.alterra.wur.nl/NL/Producten/Informatiesystemen/SynBioSys/

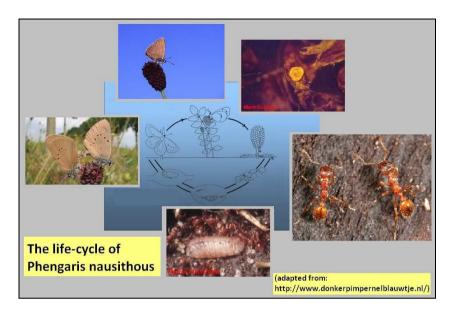


Figure 5 The complicated life-cycle of the Dusky Large Blue



Old topographical maps indicate the historical land use. Accurate maps are usually available from the 19th century onward, but also older maps often yield valuable information. Maps are always made for specific purposes and often they were drawn up for military purposes, so they will for example indicate moisture conditions or other landforms vital to troop manoeuvre and defence purposes. Also maps on archaeological finds, old monuments, the land register and even tax registers indicate the degree of productivity of the land and its use, and in turn shed light on the landscape ecological system. Understanding the rationale behind the map will enhance its meaning during the analysis.

Besides maps one should also study field names and travel descriptions or accounts of historical land use. (Historical) aerial photographs often show surprising aspects of landscape in terms of its use, but also soil conditions, which are very difficult to see in the field. Density differences or differences in moisture are reflected in vegetation (crop-marks) or soil colour and can show striking patterns of roads, riverbeds or field patterns and even floor-plans hidden below the surface.

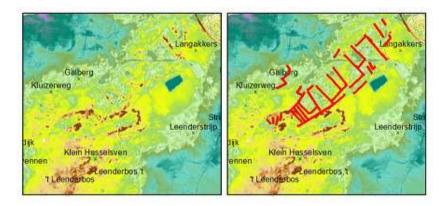


Figure 6: Historical field patterns detected on the AHN, the general digital elevation database for The Netherlands.



In a landscape, all eight levels: climate and geo(morpho)logy, water, soil, flora, fauna and mankind, are simultaneously present and in continuous interaction. This gives rise to transitions and gradients between various systems operating in this landscape. In some cases there are only a few systems present and consequently there are only a few points or zones of

contact. In other situations many systems are present, even divided into sub-systems, with many contact-zones and (complex) gradients. These gradients often harbour very interesting and often rare species, and also provide valuable information on the functioning of the landscape, since they show which systems are present and where and how they interact.

In order to define the various contributing systems, one needs to identify on which scale systems are operating in a landscape. To this end Van Wirdum⁵ distinguishes four levels on which processes are influencing vegetations:

- 1. **Operational factors** these are site conditions that affect the plant directly such as the availability of moisture or nutrients in the soil; light, humidity of the air and temperature. This includes also mechanical factors as flooding, grazing or wind.
- 2. Conditional factors these are factors that affect the vicinity of the plants to a maximum of several meters and always influence the previous Operational Factors. The distinction is not always clear, as a result of mutual influence. For example: the groundwater level controls the oxygenation of the soil, the redox-potential and the availability of cations such as calcium and magnesium and through this the acidity of the soil. The acidity in turn controls the dissolubility of phosphate and aluminium. Also plants growing side by side, sometimes respond to very different site conditions because they root in different strata of the soil.
- 3. Positional factors these factors relate to the position in the landscape, such as the geographic relief. Rainwater infiltrates into the groundwater system at a certain location, it filters through lime-rich soil layers and re-appears as seepage water with a high alkalinity elsewhere. Other examples are transport of sand or salt along a coast, or human caused acid rain or deposition of nitrogen.
- 4. **Sequential factors** these are the after effects of developments or events from the past, or historical land use. Soil formation or erosion, heavy fertilization, irrigation, flooding, etc.

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 $^{^{5}}$ G. van Wirdum 1979 – Ecoterminologie en grondwaterregime WLO-mededelingen 6:3 pp 19-24.

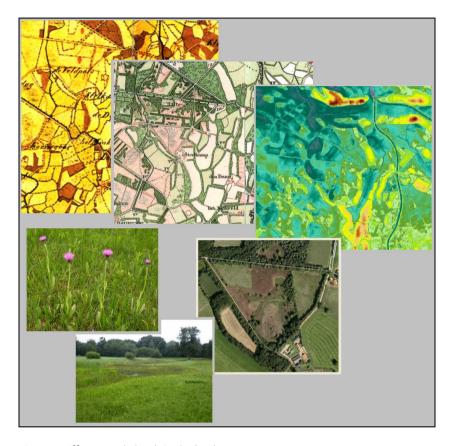


Figure 7 Different scale levels in the landscape.

2. Overview of LESA factors

2.1 Checklist

The landscape ecological analysis identifies the relationships between species and/or habitat-types with their environment, for the purpose of understanding the functioning of the larger systems behind them. This information can then be utilized to select and define areas of natural value and to define management or conservation measures.

Practically speaking this means that the analysis for vegetations and their patterns mainly focuses on the abiotic environmental conditions, the processes that govern these and the kind and degree of human influence on habitat and landscape scale. For fauna the analysis focuses on the size and quality of their habitat and range and the processes that determine these.

Below a checklist is provided for all eight levels: climate and geo(morpho)logy, water, soil, flora, fauna and mankind, on meaningful factors to examine. Taken together they constitute a full *Landscape Ecological System Analysis* or LESA. Such an analysis should always be tailored to the study-area and the relevant questions there. In a LESA it is important to zoom in from large to small and from outside to inside, from old to young and then back again, in an iterative manner. During this process one should be very clear in defining the scales and distributions of the patterns and the processes under scrutiny. The iterative nature of this exercise zooming in and out in both space and time is essential in order to connect the information obtained on different scales.

The study-area of a LESA is larger than the site involved, in order to get a grasp of all relationships of for example local climate or ground and/or surface water, one studies a wider envelope. This calls for a practical approach and per factor the envelope can differ. For example the vegetation usually only needs to be surveyed in the area itself, but sometimes it is necessary to know the broad vegetation pattern of the area. Geo-hydrological studies almost always pertain to a wide area

around the study-area. For each study, irrespective of size, also gaps in knowledge and uncertainties and assumptions need to be made explicit. Sometimes data collecting and analysis is highly specialized and it makes sense to bring in specialists.

2.2 When to use a LESA

The checklist is a tool that can be employed to develop management and conservation/restoration plans for existing nature reserves. The LESA will provide a solid foundation for taking measures, including an overview of the gaps in knowledge. It is a transparent system that accounts for all decisions that are based upon the collected information and the inferred conclusions..

A LESA is a powerful tool for the designation of future nature reserves or other projects that affect areas on a landscape scale. Examples here are:

- Designation of Natura 2000 areas;
- Infrastructural projects such as roads, railway lines, bridges, mountain passes and tunnels;
- Quarries and other forms of mining;
- Housing and industrial developments such as extensions or new development of towns and cities and industrial plants.

The LESA can help to identify the existing ecological systems in an area and their state, importance and functioning, as well as help to delineate their extent. So for the examples above:

Designation of Natura 2000 areas

- What are existing species and habitat-types in an area?
 Distribution patterns and ranges.
- o What are their ecological requirements?
- What systems are present in the area that cater for these species or habitat-types and how are they distributed?
- o Knowing the interrelationship between nature values and the landscape systems, one can define the limits of these systems and decide upon the demarcation of the limits of a protected area. So landscape ecological analysis is an essential tool for the designation of future nature reserves since it helps to define which parts of the

landscape affect the nature values and which parts do not.

- <u>Infrastructural projects, Quarries and other forms of mining,</u> <u>Housing and industrial developments</u>
 - For our economic development we need to plan housing, industry, resources and the connections between them.
 Yet at the same time we desire to have nature values, that are largely or entirely self sustainable or need little management.
 - O Undermining the landscape ecological systems that drive these nature values, ultimately leads to the deterioration of the very values we desired; but the consequential conservation and restoration measures are usually very expensive. Preserving systems is a much more economical and durable approach of nature conservation, compared to taking measures for individual species or habitat-types.
 - o In the balance of economic versus ecological values a LESA can bring the necessary understanding of the present nature values and the connected landscape ecological systems. This can be employed to make informed choices and/or create zones with different types of economic use, depending on their degree of influence on the ecological systems.
 - Performing a LESA does <u>not</u> imply that one aims at creating nature reserves everywhere. A LESA indicates the nature and functioning of interrelationships between plants and animals and their environment. This understanding can then be utilized to indicate the consequences of possible scenarios and choices. These choices are usually political in nature. So a LESA can aid politicians to make informed choices concerning spatial planning, for future generations.

As will be pointed out below a LESA is always performed in a context of a landscape and in answer to a specific set of questions. Both determine extent, depth and degree of detail of a LESA. This checklist serves to keep an overview during that process.



3. Level 1, 2 and 3 Climate, Rock and Relief

3.1 Description and interpretation of the subsoil

3.1.1 *Description of the situation:*

- Surface geology, geomorphology, and relief also using digital terrain maps.
- Geological structure of the subsoil and presence and position of aquifers (water bearing layers) and aquitards (confining or impermeable layers, with low transmisivity).
- Geochemical properties concerning for example acidity/alkalinity, salinity and redox-potential.
- Use and changes by man such as quarrying, polders, irrigation, dikes, embankments, earthworks. Also use local field and place names.

3.1.2 Description of developments and changes

- Changes in the geology only occur in geologically active areas, involving tectonics and volcanism. Also lowering of the soil due to salt, gas and oil extraction should be considered, as well as the consequences of quarrying, open cast mining and so on.
- Erosion caused by human activities. By removing vegetation from an area, the soil becomes susceptible to erosion. Examples are logging, which can cause increased erosion rates due to soil compaction, exposure of the mineral soil and making the forest floor susceptible to the terminal velocity of rain droplets; as well as the construction of roads and landings; and heavy grazing which reduces vegetation.



4. LEVEL 4 - HYDROLOGY

4.1 Surface water system

4.1.1 Description of the situation

- Pattern and depth and discharge levels of all forms of drainage.
 Also involve old and disused drains in the analysis, for they shed light on the extent of the previous system.
- Changes in the water system: changes in riverbeds and brooks, digging of channels, dikes and other embankments, retention basins, irrigation systems, etc.
- Water depth and discharge levels of rivers, brooks, channels, lakes.

4.1.2 Description of developments and changes

- Water balance of surface systems including water levels and their fluctuations and discharge levels and dynamics (rivers, brooks, channels, lakes).
- Morphology and morpho-dynamics of river beds and floodplains.
- Water quality in terms of chemical composition, as well as pollution and visibility in the water.

4.2 Groundwater system

4.2.1 Description of the situation

- The geohydrological structure of the subsoil: the permeability of aquifers and aquitards and accompanying geochemical properties.
- Groundwater levels.

 Description of groundwater flow, using data on infiltration, seepage and hydraulic head for hydrological modelling and hydrochemical patterns.

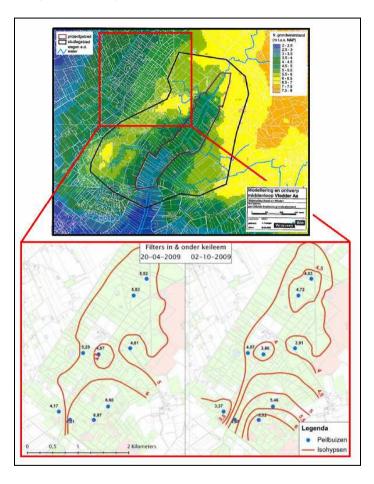


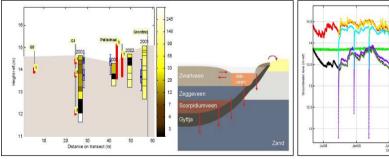
Figure 8: General and local studies on the hydraulic head in the area of Boschoord (Prov. of Drenthe, The Netherlands; adapted from Jansen et al. 2010. ⁶)

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⁶ A.J.M. Jansen, G.J. Baaijens, J. Bouwman, J. Sevink & A.C. Seijmonsbergen m.m.v. A.Th.W. Eysink, P.C. van der Molen & M. den Haan 2010. Hydro-ecologische analyse van Boschoord. Coöperatie Bosgroep Midden Nederland.

Description of developments and changes 4.2.2

- Study the seasonal and annual dynamics of groundwater levels and their relationship to precipitation and evapo(transpi)ration through time series analysis. Take into account the presence and properties of aguifers and unsaturated layers.
- Groundwater extraction: rates and peak extractions.
- Trends in hydraulic head of aguifers using time-series analysis, applied hydrological and GIS-modelling. Pay attention to the possibilities, ranges and limitations and the resolution of the analyses. Take into account which landforms and which layers in the subsoil, have been included or left out in the modelling. What are the assumptions in the interpolations between the measuring points in space and time.
- Trends in chemical composition of the water and the presence of water types (levels of: phosphate, sulphate, (bi)carbonate, nitrate, K, Mg, Fe, Ca, Mn, Na, Cl, pH and conductivity) and keep in mind the effects of solubles on the water density such as layers of rainwater on top of groundwater.



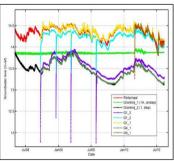


Figure 9: Transects and hydrological measurements in former pingo's in the Province of Drenthe, The Netherlands. (Van Asmuth et al. 2011⁷)

⁷ Jos von Asmuth, Ab Grootjans, Sake van der Schaaf, 2011. Over de dynamiek van peilen en fluxen in vennen en veentjes. Eindrapport deel 2, OBN-onderzoek 'Herstel van biodiversiteit en landschapsecologische relaties in het natte zandlandschap'. Bosschap, bedrijfschap voor bos en natuur.



5. LEVEL 5 — SOIL AND RECENT LAND USE

5.1 Pedogenics

5.1.1 Description of the situation

- Soil maps are an indispensable tool in a landscape ecological analysis. Soil maps on a scale of 1:10.000 to 1:50.000, provide an excellent overview of processes that have acted on the upper parts of the subsoil for the last centuries. Consult them in combination with maps on groundwater conditions. Use the international soil classification system in the World Soil Reference Base (http://www.fao.org/ag/agl/agll/wrb/default.stm).
- Soil maps can yield derivates in terms of maps of certain soil properties such as profiles of the organic top layers with humus, calcium content, salt, loam and clay content, particle size, acidity and redox-potential, gley-soils, pyrite, formation of humic layers with a decreased permeability for water.

5.1.2 Description of developments and changes

- Soil changes such as ploughing, deep drainage, creation of polders, addition of sand, irrigation and changes in soil properties due to increased salinity, etc.
- Erosion and formation of sand dunes due to mechanical damage of the topsoil or desiccation.
- Changes to soil flora and fauna and seed banks.

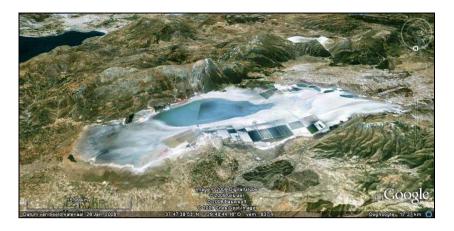


Figure 10: Changes in lake level and land-use around Lake Acigöl in Turkey. (Picture: Google Earth 2010).

5.2 Land use

5.2.1 Description of the situation

- Use of fertilizers in and around the study-area, especially in higher infiltration areas.
- Atmospheric deposition of pollutants such as nitrogen and sulphur.
- Use of herbicides and pesticides.
- Infrastructure and recreational use.

5.2.2 Description of developments and changes

- Increase in paved surfaces such as roads and housing areas.
- Changes in crops, such as changing meadows into pastures and vice versa.
- Nature and landscape development.



6. LEVEL 6 - VEGETATION

7. LEVEL 7 - FAUNA

7.1 Presence, distribution and changes

7.1.1 Description per habitat type

- Current and historical distribution area and constituting vegetation-types and abundance of differentiating species.
- Quality of the habitat type based on vegetation, habitat conditions, differentiating species and structure.
- Dynamics and trends in succession and degradation.

7.1.2 Description of species (both plants and animals)

- Current and historical distribution of the species pertaining to the quality of the area for the species (breeding, foraging, rest, molting, sleep, winter refuge).
- Size of the population internal connections between subpopulations inside an area and with other sub-populations outside the study-area.
- Quality of the population: demographics, reproduction genetic variation (especially for small sized populations)
- Dynamics and trends trends, fluctuations, risk for extinction.
- Dispersal expansion of the population to other areas.
- For some species seasonal migrations.

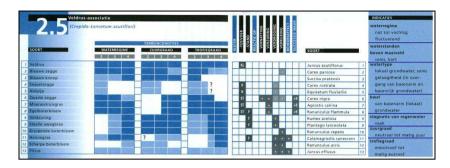


Figure 11 Example of a Dutch book on indicator species by SBB/KIWA.

7.2 Ecological habitat conditions

7.2.1 Habitat-types

- Use van Wirdum's four scale levels of processes operation in the landscape. First consider the Operational and Conditional Factors and relate the general ecological requirements to the area and the site. Usually habitat-types are composed of several vegetation-types, each having their specific ecological requirements. Use ordination techniques such as CANOCO and DECORANA to establish and quantify the relationship between presence of vegetations and abiotic factors.
- Next consider Positional and Sequential Factors. They will supply you with additional information concerning governing processes in the landscape on a scale above site level.
- Study gradients in the landscape they provide information on the presence of different systems in an area and their interaction.
- Examples of ecological habitat conditions for Natura 2000: are found on:

http://www.synbiosys.alterra.nl/natura2000/documenten/Ecologi scheVereisten/VereistenHabitat-types Dec2008.zip.

This is particular for Dutch Natura 2000 habitat-types , but it is an interesting example.

7.2.2 Species (both plants and animals)

- Species related habitat requirements, including those for species serving as hosts for others or species that have negative effects on others through predation or through displacement.
- Additional requirements concerning governing processes in the landscape on a scale above site level, such as size, spatial distribution of the various aspects of a habitat such as grain-size, combinations and terrain-heterogeneity.
- Additional habitat requirements concerning connections with other areas (meta-populations) or possible missing parts of the habitat.



Figure 12: Hottonia palustris as an indicator of carbon rich seepage water.



8. LEVEL 8 — HISTORICAL LAND USE

8.1 Historical developments

8.1.1 To do:

 Study the historical developments in and around the study-area using historical maps, aerial photographs, place and field names, historical descriptions and accounts, field observations and anecdotes.

8.2 Historical developments and human interventions

8.2.1 Analysis

- Use maps to determine why the inhabitants have used that landscape in that particular way. Why they performed certain interventions and why something occurs on a specific location. Try to establish patterns of landforms and use and find the logic behind them this will yield information on the landscape ecological system. For example: consider the location of settlements or farms in relation to roads and trails, their pastures and fields. What are the moisture conditions in the soils, what did they reclaim and what not.
- Be aware of the fact that maps are abstractions of reality and are usually made with a particular aim. This implies that choices were made regarding the nature and accuracy of information displayed on a map. Therefore it is advisable to also consider aerial photographs of the same area and period, on which the maps are based.

- When maps of different periods of time are available describe the changes in the landscape and specifically consider water management, vegetation structure, land use, infrastructure and settlement.
- Also consider other studies from the area that might shed light on factors such as evapo(transpi)ration, succession, plantation, changes in management, changes in connectivity, recreational use, pollutants and fertilizers such as phosphate or nitrogen deposition.

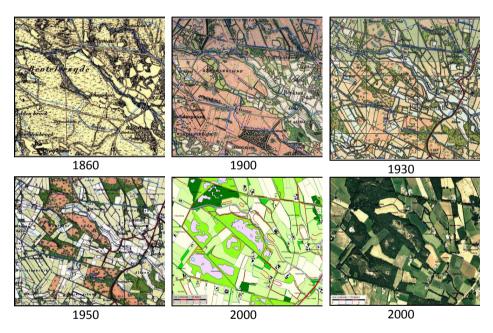


Figure 13 Development of the landscape around the Buitenbeek (Prov. of Overijssel, The Netherlands).



9. Integration information

OF

9.1 Confrontation of patterns and trends

The collected information needs to come together to be synthesized into an overview of the nature and functioning of the landscape ecological system. It needs to demonstrate how the landscape was functioning originally, what has happened to it, how it is functioning now, and it should provide explanations for the distribution patterns of flora, vegetation and fauna.

9.1.1 Habitat-types

- Distribution and quality of habitat-types and their distribution patterns in relationship to the four landscape factors. One can also employ ITERATIO-analyses, to translate vegetation maps into maps of ecological habitat conditions using indicator species⁸.
- Compare the results in the trends of the individual ecological factors with trends in development or degradation of habitattypes.

9.1.2 Species

 Compare the current and historical distribution of the species, pertaining to the quality of the area for the species (breeding, foraging, rest, molting, sleep, winter refuge) with the factors as discussed above.

⁸ Holtland, W. J., ter Braak, C. J. F. en Schouten, M. G. C., Published Online: Jan 14 2010; Iteratio: calculating environmental indicator values for species and relevés, In: Applied Vegetation Science (International Association for Vegetation Science).

 Compare the trends of individual species with trends in other species and the various factors as discussed above.

9.2 Determinative processes in the area

Determinative processes are, as the word says, determining the presence and trends in the dynamics of habitat-types and species. For conservation and restoration purposes, they are the 'handles' to 'tune' an area they are the means through which we can regulate those conditions for habitat-types or species, that are under our influence.

The determining factors for the occurrence and quality of natural values can be very different, such as: chemical processes in the soil, groundwater dynamics, trophic interactions, connectivity, influence of human activity such as agriculture, infrastructure, water use or recreation.

In the analysis, all the factors for all eight hierarchical levels: climate and geo(morpho)logy, water, soil, flora, fauna and mankind, are included. They are included from large to small, from outside the area to inside and from old to recent and in this way patterns, processes and trends are revealed, that have shaped the landscape as it presents itself to us.

9.2.1 To do:

- Determine processes and their scale in space (pattern) and time (trend), that determine the presence and quality of habitat-types, in a positive or negative way.
- Summarize the processes in a block diagram. This will force you to combine patterns and processes and to establish relationships between these.
- Determine processes and their scale in space (pattern) and time (trend), that determine the presence, range and quality of the habitats and population sizes of species, in a positive or negative way. Here one should also involve trophic interactions, and degrees of connectivity or range fragmentation.

Geographical Information Systems are a wonderful tool to synthesize all the various streams of information. Visualize the distribution patterns of habitats and or species and find correlations between their (degree of) presence and abiotic conditions or processes. A block diagram is an extremely useful tool for summarizing and explaining the workings of the landscape ecological system to the larger public.

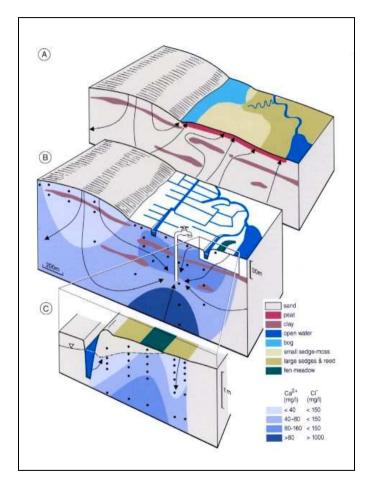


Figure 14 Block diagram, linking geomorphology, soil, historical land use and water quantity and –quality. (from: Grootjans & van Diggelen 2009).

9.3 Evaluation and dealing with uncertainties

In order to test a landscape ecological description, concrete hypotheses are postulated, concerning the functioning of various landscape elements. Based on these hypotheses detailed predictions are made concerning phenomena for specific locations that have not been studied yet. Examples are the presence of certain indicator species, or the occurrence of seepage or particular sediment types or their particle size, a certain soil profile or the presence of historical land features such as old ditches or embankments.

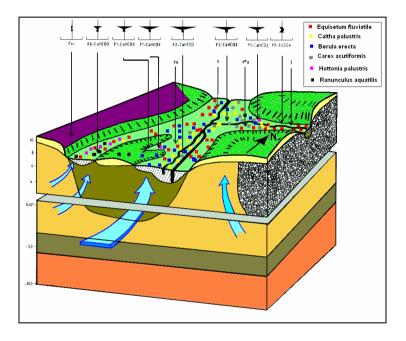


Figure 15 Block diagram of a part of the Drentse Aa valley (Drenthe, The Netherlands) used for the analysis of the distribution of species in response to specific groundwater flows. (From: Everts en de Vries 1991).

These hypotheses are then tested and verified through measurements, and field visits and if in that process hypotheses have to be rejected, it simply means that our understanding of the landscape is still falling short and that our model has gaps or flaws that need to be solved. So an

iterative process takes place where the acceptance or rejection of postulated hypotheses, leads to further hypotheses that need to be tested.

Hypotheses can only be tested using current knowledge. If that state of knowledge is insufficient to explain the observations, then we have a gap in our knowledge. These knowledge gaps are a full and integral result of the analysis. So testing of hypotheses goes on until either a sufficient number of relevant cases have been understood, or until we have reached the limits of our understanding given the available knowledge.

One can evaluate a completed LESA with regards to the following criteria:

- The landscape ecological system analysis should be a consistent and logical line of thought, based on various scientific disciplines, on how a landscape has originated, how it has evolved, how it functions, and how it has been used. If this is the case then the analysis can be qualified as good.
- A landscape ecological system analysis should yield a list of gaps in knowledge, ranked in importance. Gaps in knowledge are a valid and valuable result of the landscape ecological system analysis. This is essential for conservation and restoration measures, for one has to be able to decide whether a particular gap in knowledge is critical or not, in order to take the right measures or to decide if further studies are necessary. Large gaps in knowledge can also be included in the future monitoring or can be a reason to include future studies in the conservation or restoration management plan for that area.
- This checklist provides an overview of the most relevant aspects
 to study in any area, but its use should be tailored to the original
 goal of the landscape ecological analysis, the questions the
 analysis set out to answer. They determine the relevance and
 priority of the various aspects to study and their level of detail.
 This should be kept in mind during the analysis.
- One cannot be an expert in everything, so it is advisable to involve experts from other fields, in the study of an area.



10. APPLICATION

10.1 Development vision

10.1.1 Developmental series

To every location in the field belongs a natural series of vegetation-types, but only if conditions are left undisturbed. This is the primary succession series of vegetation-types. Depending on the type of land use, these vegetation-types are replaced by semi-natural types such as heath-land. For The Netherlands for example these succession series have been described in great detail in *Wegen naar natuurdoeltypen*⁹. Sometimes for particular areas regional succession schemes have been drafted, for example for the brook system of the Drentse Aa¹⁰. In The Netherlands, these systems of succession series are used to define targets for nature conservation for particular areas.

10.1.2 Potential for nature development

In order to identify the potential for nature development or the conservation or restoration of existing nature values, one first has to establish the position of the current habitat-types or vegetation-types in the succession series. Vegetation or habitat-types are classified according to quality and even degenerated forms that do not belong to a vegetation or habitat type anymore are identified.

The choice of a target vegetation is usually based on either an understanding of the landscape ecological system, or solely based on

⁹ J. Schaminée en A. Jansen, Wegen naar Natuurdoeltypen IKC-Natuurbeheer Wageningen. 1998 rapport 26 en in 2000 rapport 46.

Everts, F.H. en de Vries, N.P.J. 1991. De vegetatie van beekdalsystemen. Een landschapsoecologische studie van enkele Drentse beekdalen. Historische Uitgeverij Groningen. 222pp.

strategic policies. In both approaches, the choice of a target nature value should be focussed on a durable result, fitting to the landscape ecological characteristics of an area, in combination with the necessary conservation, restoration and management measures. In the long run, the aim should be to have a self sustainable system and to reduce management effort, with increasing nature values.

So it is essential to estimate which target vegetations are feasible and what is necessary to realise and maintain them. Besides well developed vegetations, one usually also finds less well developed or even degraded communities in a given location. This is usually caused by eutrophication, desiccation, acidification or fragmentation. These degraded vegetations can be used as indicators of the current conditions and the existing potential. On former agricultural soils, the redevelopment of nature values strongly depends on the degree to which restoration measures need to be taken. One can think of:

- Restoring the original relief.
- Restoring ground and surface water conditions and regimes.
- The degree of eutrophication due to dumping of fertilizers and manure.
- The restoration of healthy soil flora an fauna.

The development series, discussed above are well developed for Dutch situations in: Wegen naar natuurdoeltypen¹¹ and for grasslands in Veldgids ontwikkeling van botanisch waardevol grasland¹². In SynBioSys also succession schedules have been included. One needs to keep the followings aspects in mind:

- The choice and the development of target vegetations for the short and the long term in space and time.
 - Habitat type: distribution, area, quality development strategy and dynamics.
 - Species: distribution and connectivity, area, range and quality of the habitat, population size and dynamics.
- What course leads to which goal.
- Choice and motivation for long term measures.

¹¹ J. Schaminée en A. Jansen, Wegen naar Natuurdoeltypen IKC-Natuurbeheer Wageningen. 1998 rapport 26 en in 2000 rapport 46.

¹² DLG en IKC-Natuurbeheer. 1998. Veldgids ontwikkeling van botanisch waardevol grasland Publicatie C-18, Wageningen.

 Choice and motivation for short term measures, where one needs to distinguish between measures for lasting restoration or survival. The latter can never replace the former.

10.2 Present and desired nature values

10.2.1 To do:

- Establish the degree of similarity or difference between the present and the desired nature values. There can be differences in quality or size of populations, habitats or ranges.
- In nature reserves: what are the targets for an area for which it is designated: which habitat-types or species are present, which need conservation or restoration measures.
- What is the conservation status of habitats or species and what measures are needed to bring them in a favourable conservation status.
- Are there conflicts between the targets? Conflicts can exist between habitat-types and species in an area, or among habitattypes or species.



Figure 16 Pingo in the Brackvenn (Hautes Fagnes Belgium). Fen and raised bog vegetations in a geomorphological monument from the last glaciation.

10.3 Extrapolation – perspective for habitat-types and species

Extending the results of the information from the landscape ecological analysis to conservation or restoration measures for species habitats and habitat-types, requires great care. Usually several scenarios are developed in order to have options when the outcome of the analysis is discussed

with authorities and stakeholders. During these discussions there can be a need to extrapolate the results of the analysis beyond its confidence limits. In these cases, the degree of certainty of the conclusions decreases rapidly. This is not necessarily a problem, provided that the confidence limits are clear and that the extrapolation process is transparent. A few aspects can be kept in mind during extrapolation:

10.3.1 Habitat-types

- Identify trends in the developments of the extent and quality of the habitat type under current conditions and management.
- Develop perspectives for improvement of the quality of the habitat type, or the expansion of its extent, inside or outside the current nature reserve. Also develop the possibilities of establishing connections with other nature reserves.
- Investigate the kinds of land use in and around the study-area, that might impede conservation, restoration or expansion measures. Develop scenarios for these.
- What are the interactions among habitat-types: will one type decrease in size in favour of another? Interactions between habitat-types and species?
- What succession series exist among habitat-types in the studyarea, what are their time-frames.

10.3.2 Species

- Identify trends in the developments of the population size, range and quality of their habitats under current conditions and management.
- Develop perspectives for improvement of the quality or expansion of the ranges of the species, the stability and expansion of the population size and their habitats inside or outside the current nature reserve and develop the possibilities of establishing connections with other nature reserves.
- Investigate the types of land use in and around the study-area that might impede conservation, restoration or expansion measures. Develop scenarios for these.

- Does the proposed management interfere with measures for other nature values such as habitat-types or other species: will one species or population decrease in size or quality in favour of another?
- What are the interactions with other areas do species migrate into the study-area, or do they overflow into the study-area from neighbouring reserves?
- What succession series exist among species in the study-area, what are their time-frames.

Always take sequential or time aspects of habitat conditions into account when evaluating trends in developments. Certain human activities from the past can have a delayed effect on the (a)biotic conditions, but the same holds true for certain natural processes. Examples of the former are increased acidification due to lowering of the ground water levels, or slow travelling plumes of pollutants in the sub soil or internal eutrophication due to over-fertilization in infiltration areas. Examples of the latter are natural succession such as effects of forest development or from for example paludification.

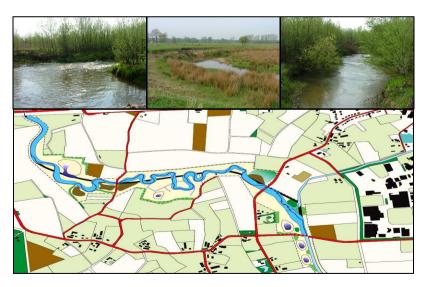


Figure 17 Planned nature development along the river Smalwater in The Netherlands. Above the result after two years of development.

INTERMEZZO 1: DESIGNATION OF NATURE RESERVES

A major part of nature conservation consists of designation of areas for specific habitat types or species. After the designation phase, the current and desired conservation status of the various nature values need to be established. This forms the basis for conservation objectives and for management planning. An appropriate assessment can be used to establish the degree of influence of current land-use on the nature values.

The LESA is an ideal instrument for this phase. It helps to:

- Establish the nature and the system-boundaries of a sustainable landscape ecological system.
- To establish how the landscape ecological system has functioned, if and how it has changed and in what way.
- To determine the necessary environmental conditions for the nature values and to what degree conservation or restoration measures are needed.

For example: Clara Bog in Co. Offaly, Ireland



(Picture: Google Earth 2010).

This bog was established as a National Nature Reserve in 1987, based on the existing boundaries of the existing peat reserves at the time.

In the Irish Midlands, raised bogs were formed in depressions between ridges dating from the last glaciation, called 'eskers'.



View from the bog shows the elevated ridge north of the present bog.

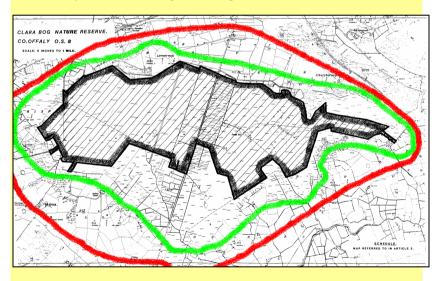


(Picture: Google Earth 2010).

Between these ridges and the bog itself, valuable transition zones called lag-zones have been formed. They are characterized by rare gradients from calciferous to acidic vegetations, for example many orchids find their home here.



However, these areas are under threat from peat cutting, drainage and agricultural run-off from the esker ridges. This in turn negatively affects the peatland itself, causing drainage and structural changes in hydrology and the shape and functioning of the bog.



The black line indicates the extent of the nature reserve.

However the **red line** indicates the approximate position of the landscape ecological system boundary of this bog based on the position of the eskers and laggs.

Using this system boundary to shape the nature reserve would have yielded a more sustainable reserve, indicated by the **green line**, which needs minimal management and will be cost effective.

10.4 Bottlenecks and options for measures

10.4.1 *To do:*

- Bottlenecks can be regarded as cause-effect chains. A specific form of land use or management or a specific intervention or measure has (a number of) (a)biotic effects. This leads for example to the deterioration of the quality or extent of a habitat type; or the size and quality of the population of a particular species. The various factors summed up in the previous paragraphs enable you to get an overview of the functioning of the landscape ecological system, how it has evolved, how it has changed, what is left and what can be done about it. That sheds light on the entire chain of cause and effect.
- The urgency of a bottleneck can be determined by estimating if the continuation of the situation leads to loss of habitat-types, species or restoration possibilities.
- Define scenarios with options for measures to be taken for each bottleneck and indicate if a combination of measures is needed to provide a solution. Distinguish between measures with a fundamental nature, that deal with the cause of the problem; or measures that only provide mitigation of the problem and are therefore only effective temporarily. Also specify the moment in the year, frequency and nature of management measures.

10.4.2 Per scenario

- Specify which measure deals with which bottleneck and whether the measures deal with the cause or just the symptoms of the problem.
- Indicate the effects of measures in space and time.
- Interaction and order: the effects of a measure can depend on (the order of) other measures. A consistent and logical order of measures is required in order to obtain the desired results.
- Verify if measures have side-effects with regards to other nature values and how these risks can be kept to a minimum and in check.
- Check for possible no-regret measures.

- Landscape Ecological System Analysis -
- Fine-tuning: provide for checks in the measurements to adjust them according to the situation.

12 SUMMARY SCHEDULE

Below a summary schedule of a LESA is provided:

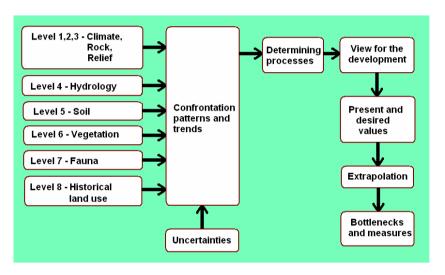


Figure 18 Summary schedule for a LESA.

INTERMEZZO 2: SYSTEMS APPROACH TO THE INTERACTION OF FAUNA AND VEGETATION

Often the protection and conservation of vegetation and fauna values go hand in hand. A LESA can in these cases be employed to:

- Establish the nature and the landscape ecological system-boundaries of the vegetations.
- To establish how the landscape ecological system has functioned and determined the presence of the vegetations. Also if and how it has changed and if conservation or restoration measures are needed.
- This analysis can then be combined with information on the presence, distribution, requirements and life-cycles of the occurring animals. This will determine the carrying-capacity of the area and the zoning of different types of protection and land-use. This will help to combine ecological goals with economic activities in a sustainable manner.

For example: Soguksu National Park in Central Turkey



Soguksu National Park lies north of Ankara and is established in a mountainous area. The actual ecological zone, indicated with the fat brown line, and surrounds the actual reserve, indicated in green.

The National Park is intended for the protection of the Pine forests, which are a home to many important animals such as: Bear, Fox, and Jackal; as well as many species of Eagles, Vultures, Harriers, Buzzards, Kites, Falcons and Owls.



(Picture: Google Earth 2010).

In the red circle lies the actual National Park of almost 1000 ha, of which 30% has a recreational function and 70% is zoned for nature conservation. For such a situation one needs a good assessment of interactions of vegetation and fauna. After all the condition and prospects of the forest vegetations, determines their capability in providing food and shelter for these animals. So we need to look at:

- The condition and structure of the forests; which parts are vulnerable or threatened. What management measures can be taken?
- The water supply for forests and pasture vegetations. The interaction with the thermal springs, for which the area is famous.
- Is the zoning of the recreational use in accordance with the habitats and ranges of the wildlife and their life-cycles. How does this interact with human land-use?

It is the combination of the ecology and distribution of the forests and the possibilities for their sustainable management, that determines the extent of the area for the protection of these wonderful animals in these rugged mountains. It has to be combined with economic use by man. The creation of the National Park Soguksu is therefore a major contribution to Turkish nature conservation



13 Rules of Thumb

PHASE I: FIELD SURVEY

The field comes first and last.

Always go to the field and have an open eye and mind for what it has to tell
you. Formulate hypotheses based on your desk studies and check these in the
field. The field has a story to tell.

Visit the study-area often and under all weather conditions.

 Visit the study-area often, in all seasons and under all -particularly extreme weather conditions, to see how it responds. It shows you the extent as well as the limits of the system.

Collect sufficient data.

Talk to people who have worked in the study-area both researchers as well as
farmers or foresters and so on. Ask them about their activities: what it is they
did and how, what struck them about this area, how they used the soil. Enquire
after place and fieldnames and anecdotes. Learn the local history and try to
reconstruct the main forms of management.

Rely on accepted knowledge and facts.

• There are two sets of questions: the first one is based on very simple and generally known principles such as: 'water flows from high to low', or 'water cannot be compressed'. The other set is based on a large integrated multidisciplinary knowledge base regarding indicator species, geology and geomorphology and cultural history. Both sets of questions are necessary.

Keep an open mind.

 Use all your knowledge and all the facts and information, but simultaneously, keep a fresh mind! Simple questions are often difficult to answer but are also very relevant. Aristotle said: 'curiosity is the foundation of all knowledge' so you have to keep asking: 'why'? Also for obvious things, nothing is irrelevant. At the same time prioritize the questions and try with an open mind and all your knowledge to grasp the 'working' of the landscape.

PHASE II: FACTORS

A growing iterative process: zooming in and out.

- Approach the area in a broad context and then zoom in on the landforms. So
 first use geo(morpho)logic information and gradually zoom in on site
 conditions. To detect patterns and if possible clues towards processes.
- Next is collecting information on site conditions through measurements and analyses, in order to explain observed patterns. Some things are only relevant on a very localised level of several square meters, but can only be understood within a larger context. Think of the four scale levels of processes operation in the landscape by van Wirdum.
- After this site observations are put in a bigger perspective again this is an
 iterative process that will occur several times. These iterations, together with a
 growing understanding of the study-area, will direct the research. It is
 therefore that a LESA can never follow a cook-book approach or be carried out
 using standard protocols.
- This order of things and the iterative nature of the LESA, ensure that important questions, observations or measurements are not omitted, or that locations are left unstudied.

Use your basic information.

- Use all available map material, surveys, observations and measurements and be aware of their strengths, limitations and possible mistakes. Always compare maps to the situation in the field.
- Study maps with the same knowledge and questions, but also with the same open mind, as you study the field itself. Combine existing knowledge on indicator species, succession series, soil types etc, with the surveys and propose new questions. Try to spot patterns on maps and explain them. Continuously ask yourself why something occurs on that specific location.

Visit extraordinary locations in the study-area.

Visit and study extraordinary locations and gradients in the field. These are the places where one can study the nature and scale of the processes happening in the field. These can be locations where one finds unusual combinations of species or landforms. Always place these in the context of their surroundings: why is this here? What makes this so special? What is happening here? What systems are at work here and how do they interact?

PHASE III: CONCLUSIONS AND EVALUATION

Only start writing when you have the big picture in your grasp.

- After the field and desk studies, and based on all available information: propose verifiable hypotheses and test these. Distinguish clearly between issues of primary and secondary importance. These are determined mainly by the goal of the study.
- The main line of thought based on your verified hypotheses is: how did it evolve? How did it function? What has happened to it? What is the situation now? This is essential for the assessment of the functioning of the system, and will allow you to evaluate current use and propose possible conservation and management measures.
- In this phase important gaps in knowledge are also identified, such as lack of information or data, processes that could not be verified, etc. These are all reported and agreements are made on how they are handled. It is also useful at this stage to present these questions to other experts and people familiar with the study-area. Often discussions help to clarify salient points or bring them more to the surface. Only when the general line of thought has become clear and gaps and questions have been identified start writing.

When is it sufficient? When predictions hold.

- Every landscape ecological analysis has to result in a model that links the observed patters to underlying processes.
- At that moment, one should be able to make predictions about the functioning
 of the system such as the occurrence of species or seepage or soil properties at
 specific but hitherto unvisited and unstudied locations. These predictions need
 to be tested in the field or through existing data.
- If the prediction fails it means that the understanding of the system is as yet
 insufficient and one has to put in more effort to gain understanding. New
 information and insights will always develop in the years after, but testing a
 prediction about something unknown, is the best one can do for that moment.

Uncertainties

- One is usually short of time, equipment, data and information, so you got to make do with what you have. When more studies are called for this has to be identified and reported, one still has to give the best possible interpretation based on the available facts. The assumptions and lines of thought should be transparent and made public, so that the conclusions and the measures based upon these, are open for discussion.
- When conclusions are based on very few pieces of data, it is advisable to seek support from experts on this particular topic. One cannot be an expert in every field oneself. Also with monitoring in mind, it can be useful to adjust measuring points or add to the existing network.
- All uncertainties and gaps in knowledge are indicated in the final report and it
 is explained how they were weighed and used, and how they should be
 considered in the future. Uncertainties can lead to specific research or can give
 suggestions for monitoring. Do make sure that you have used all available
 relevant and current information, should the report be used in a legal case.

Looking back: finding the balance between 'madness and dedication'.

- Modesty is a virtue. One has to account for the range and significance of the analyses, as well as for its limitations and the gaps in knowledge and information.
- A landscape ecological study is intrinsically a process of growing understanding
 of the functioning of the system of an area. One's comprehension constantly
 develops through making hypotheses, by testing their predictions and
 subsequently adjusting the model.
- Landscape ecological studies demand to rise above one's own limitations in thinking, with often few means and or resources. That is a continuous learning curve. By involving others, one learns faster, for everybody asks different questions. By visiting certain areas often, one builds a frame of reference which can be used for other cases. In this manner one learns not to overlook things, or fail to detect species and particularly to notice what is not present in a given location in comparison with others.

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