# The history of identifying ecological characteristics biology essay

[Science](), [Biology]()

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## Introduction

As part of the Integrated Closure Planning (ICP) project pilot program Suralco wishes to define potentially viable land uses for concession areas currently under their control. For areas that are suitable and appropriate for rehabilitation to approximate pre-mining ecological conditions, Suralco would like an index to monitor progress in ecological rehabilitation towards a self-regenerating ecosystem. A draft index was initially developed by Suralco. For the purpose of the ICP project it was considered that the draft index required further expansion to achieve the aim of being a useful tool to monitor progress in ecological rehabilitation[1]towards a self-regenerating ecosystem for the selected pilot sites. A workshop, hosted by Suralco and Alcoa, was held with the Suriname Bauxite Institute (BIS) on 17 and 18 January 2012 in Paramaribo to obtain BIS's input on the proposed approach to ICP. The draft Reforestation Index outlined in Section 3 was presented during the workshop and BIS expressed their support for the proposed approach, with no objections or concerns raised.

## Assumptions and Limitations

There is an inherent uncertainty with on-the-ground implementation of rehabilitation techniques, natural dynamics, and variation in restored areas. The process of rehabilitation and the index will therefore have to be iterative and flexible to address issues as they arise during the rehabilitation period.

The index and its results should be reviewed regularly to ensure that the criteria, indicators and target values continue to be appropriate and representative to meet the objective (essentially an adaptive management process).

## Scope of Work

The revision of the draft index has been undertaken in accordance with the Terms of Reference of a proposal of 5 August 2011 and involves the following phases: Phase 1: Identifying the ecological characteristics that suitably represent the goals and objectives of the index. Phase 2: Developing a range of measurable indicators for each selected characteristic. Phase 3: Setting target values for each indicator to represent progress against the criteriaPhases 1 and 2 are outlined in Sections 3. 1 and 3. 2 of this memo. The proposed steps for completion of Phase 3 are outlined in Section 3. 3.

## Preliminary Results

## Phase 1: Identifying Ecological Characteristics

A literature review of Neotropical forest ecosystems, which are relevant to Suriname, and the principles that underpin ecosystem restoration monitoring was conducted as the first phase of the process (see Annex 1 for bibliography).

## Ecosystems in Suriname

Suriname lies within the Coastal Plain of northern South America, separated from the Amazon catchment/basin by the Guiana Shield, but still considered to be part of the Amazon system. Despite its relatively small surface area, the country has a highly diverse flora and fauna, with over 5, 000 fern and higher plant species present. More than 1, 000 of these are tree species and over 80% of the country is still covered with its original vegetation. Of the original forest cover, 90% remains intact, the greatest proportion of any country worldwide. The fauna is largely Neotropical in origin, with over 150 recorded mammal species and over 650 birds. Suriname falls within the Guianan Ecoregion, as defined in the Conservation Science Program of World Wide Fund for Nature (WWF, 2001). Vegetation types in the Coastal Plain of Suriname form a diverse matrix of ecosystems. In the Coermotibo Bauxite Concession Area, the vegetation types include highland vegetation on well-drained ridges dominated by formerly or presently cultivated land (including secondary forest regrowth) and, further south, by Mesophytic (high dryland) forest. Typically, the Mesophytic forest is rich in species and covers about 80% of Suriname. It also occurs in the other Guianas (although with different species compositions) and is well represented in conservation areas. High and Low Xerophytic forests tend to develop on ridges where bauxite is found close to the surface. This forest type is restricted to excessively drained soils that desiccate at least during the dry season, on soils with a thin, permeable top layer overlying a solid substrate such as laterite/bauxite hardcap or basement rock. Savanna (shrub savannas) and Savanna forest (tree savannas) dominate the sandy areas of the Zanderij landscape. Savannas are scattered in isolated patches throughout Suriname's forests, wherever excessively drained sandy soils are found. These vegetation types only cover a total of 1% of Suriname, but are remnants from the Pleistocene when the climate was more conducive to this vegetation type and it was more widespread. In the lower lying areas, herbaceous swamps are interspersed with smaller areas of high swamp forest and high seasonal swamp forest. Swamp areas are inundated most of the year, allowing accumulation of a peat layer on top of the soil layer. Secondary swamp forests (e. g. in previously cultivated, disturbed areas) replace disturbed high swamp forests, but exhibit a much lower biomass and are comparatively poor in species. A description of the floristic composition of the Moengo Hills in eastern Suriname is provided in annex 2 for reference purposes, as is a biological description of three sites (prior to mining) in the Para, Commewijne and Marowijne Districts in Annex 3.

## Principles of Restoration

During both the development of the monitoring program and the implementation thereof, it is imperative that the stochastic nature of ecological communities in a changing environment is recognized. Ecological succession theories provide a conceptual framework for a restoration trajectory, but the reconstruction of ‘ historic’ ecosystems may be an unrealistic goal, particularly in light of the potential impacts of climate change and where the surrounding environment is subject to change (Choi, 2007). Consequently, the concept of a restored site being regarded as a long-term applied iterative management exercise must be borne in mind. The application of adaptive management thereto is also essential. Regrettably, limited post-restoration monitoring and research has provided relatively few opportunities to improve the theory and practice of ecological restoration in mining (Cooke & Johnson, 2002). The establishment of a set of realistic and dynamic goals for the future (instead of the past environment), assuming potential multiple trajectories, the adoption of an integrated spatial approach (ecosystem or landscape) for both structure and function (instead of an ad-hoc agricultural or gardening approach to management), and the evaluation of rehabilitation/restoration progress via explicit criteria based on quantitative inference is therefore recommended (Choi, 2007). The successful monitoring of ecological restoration (Choi, 2007) is dependent on a range of prerequisites, including: sufficient ecological understanding; realistic goals; adequate restoration plans based on a systematic approach; explicit and quantified evaluation criteria for restoration success; andthe absence of significant social, economic, and political constraints.

## Monitoring Methodologies

Rehabilitation monitoring can be approached in multiple ways. Bautista and Alloza (2009) summarized these into three main methods; measuring achievement of specific goals and stages, direct comparison with reference sites, and assessment of ecological system components (providing indications of ecosystem quality). Measuring achievement of goals and stages is appropriate where specifically defined objectives have been developed for the restored area, for example wood production, flood control or provision of some other ecosystem service. Reference areas are a common and widely advocated approach where restoration goals are set using comparable areas to the rehabilitation target area. Finally, the assessment of ecosystem quality is related to existing tools and methods for monitoring ecological systems which include a wide set of attributes to evaluate the status of selected ecological system components. These attributes may cover authenticity, representative elements of forest health, environmental benefits and social and cultural values (ecosystem services). Given the lack of published information about ecosystem attributes of Neotropical forest in Suriname, the use of reference areas[2]are considered the most effective approach to developing monitoring targets[3]. This will enable site-specific information to inform the selection of target values, resulting in a more accurate and achievable goal. Reference sites for the Suralco Reforestation Index have not yet been defined, but will need to be considered in the next phase of index development. In instances where appropriate reference sites no longer exist, as is the case in the eastern part of Suriname (Moengo), expert opinion will have to be relied upon to identify appropriate indicators (e. g. relevant species) and associated target values. The following issues must be considered when applying a reference site approach: A single reference site represents a single state or expression of ecosystem attributes. The reference that is selected could have been manifested as any one of many potential states that fall within the historic range of variation of that ecosystem. The reference reflects a particular combination of stochastic events that occurred during ecosystem development. Similarly, an ecosystem that undergoes restoration can develop into any of a potentially large array of states. Any state that is expressed is acceptable as restoration, on condition that it is comparable to any of the potential states into which its reference could have developed. Consequently, a single reference inadequately expresses the constellation of potential states and the historic range of variation expressed by the restored ecosystem. Therefore, a reference is best assembled from multiple reference sites and, if necessary, other sources. Such a composite description will provide a more realistic basis for restoration planning. A reference site is normally selected for its well-developed expression of biodiversity, whereas a site in the process of restoration typically exhibits an earlier ecological stage. In such instances, the reference requires interpolation back to a prior developmental phase for purposes of both project planning and evaluation. The need for interpretation diminishes where the developmental stage at the restoration project site is sufficiently advanced for direct comparison with the reference (SER, 2004). In the context of the Jarrah forest in Western Australia, a State and Transition Model[4]was developed for Alcoa as a conceptual model to improve understanding of the potential trajectories of the system, inform the selection of appropriate indicators to measure rehabilitation/restoration success for various seral stages, and highlight the implications of various potential management interventions (Alcoa World Alumina Australia, 2007). The development of such a model may be helpful in the Surinamese context, recognizing though that in order to be of value to Suralco such a model should incorporate stochastic elements, recognize thresholds, and through a triage approach inform cost and ecologically effective management options. Based on consideration of the above issues a list of criteria has been proposed (refer Section 3. 2) to represent the rehabilitation objective, but which are also able to be realistically integrated into a monitoring program. In developing the proposed criteria the following assumptions have been made in regard to the requirements for this monitoring program: Indicators should be measurable using basic field observations, be sensitive to variations in environmental stress and responsive in a predictable manner (Bautista and Alloza, 2009). The types of observations to be selected should enable measurement by Suralco environmental field technicians or government staff, after moderate training, to the greatest extent possible. The need for observations/surveys by external experts should be limited as much as possible; The monitoring program should not incur excessive costs or be overly complex to implement; andThe monitoring timeframe should primarily address ecological rehabilitation over a 3 to 5 year period[5], but enable monitoring up to at least 10 years in the event that the Government of Suriname or members of academia wish to do so.

## Phase 2: Proposed Criteria and Indicators

Phase 2 of the draft index revision involved proposing criteria and indicators for each of the selected characteristics (refer Tables 3-1 and 3-2). According to Ruiz-Jaen and Aide (2005) restored ecosystem characteristics can be categorized into three major attributes; diversity, vegetation structure and ecological processes. These are viewed as essential for the long-term persistence of an ecosystem (Elmqvist et al. 2003; Dorren et al. 2004). The proposed criteria have been placed into these three categories. The list of criteria and potential indicators are presented in Table 3-1 and Table 3- and a discussion on each group is provided below. Diversity represents the species abundance (number of individuals per species) and richness (number of species) present in the rehabilitated area. When developing criteria for this attribute it is aimed to include a variety of taxa in the index, for example plants, insects, small mammals and birds. The following is noted for each: Plant diversity is a key priority in the first few years of rehabilitation. Changes in the diversity and abundance of pioneer, secondary and predicted dominant species provide useful information relating to the current successional stage of the ecosystem and its potential trajectory towards a self-regenerating ecosystem. Maturity in this context relates to the structure and functioning of the ecosystem rather than age of individual organisms. The rate of faunal recolonisation depends on the species. Generalist foraging mammals (with high reproductive potential) such as mice recolonize quickly in early years of rehabilitation capitalizing on empty ecological niches, but population numbers then decline, whereas reptiles have very slow return rates (more than 8 years) (Nichols and Nichols, 2003). There have been a reasonable number of studies using insects as indicators of ecosystem health. Ants, termites and nematodes are common in forest ecosystems and are reasonable easy to monitor. Due to the anticipated maximum monitoring time period of 10 years, small mammals and birds were selected as the most appropriate indicators for faunal recolonisation due to the ease with which they can be surveyed, but ants, termites and nematodes could be included where sufficient identification capacity exists. Rodents were considered a suitable indicator to represent generalist foragers, but appropriate species should be carefully selected based on colonization characteristics, typical forage, ability to react to disturbance etc. Bats are also commonly used as indicators, however identification of species would require expert assistance and this was therefore excluded from the criteria. Vegetation structure is one of the simplest criteria to measure, which can show visible progression particularly in the early stages of rehabilitation. Criteria such as vegetation cover, plant germination and vertical structure provide useful information and can be easily monitored. Other suggested criteria include basal area, tree health and abundance of recognized pioneer species. All of these indicators are relatively simple to measure. Ecological processes include the provision of ecosystem goods and services such as nutrient cycling and biological interactions. Monitoring these processes provides information on the resistance and resilience of the ecological system, in other words, the ability of the system to survive damage and recover from natural disturbances. Ecological processes are difficult to measure due to the complex biological interactions that characterize them. Nutrient cycling, for example, is a key process in ecological systems but it often requires complex or expensive activities to holistically measure it, such as the assessment of soil organic carbon concentrations. Alternative measures for nutrient cycling relate to soil features which are used below. Monitoring seed dispersion, pollination and erosion are also useful indicators for ecological processes as they are simpler to monitor, adequately representative of ecological condition, and in a practical applied sense, avoid sample handling and analytical costs. The set of criteria and measurable indicators that have been recommended for application by Suralco are specified in Table 3- below.

Table 3-: Proposed Criteria and Potential Measurable Indicators

## Ecosystem Attributes

## Criteria

## Measurable Indicators

## Vegetation Structure

Vegetative coverPercent aerial coverVertical structure/Basal areaHeight of understory and canopy, and basal growth. Tree healthIncidence rate of death/disease (no. of plants per unit area)New growthNumber of new growth per unit area

## Ecological Processes/ Resilience

Nutrient cyclingPercent litter cover[6]and percent cryptogram cover. Possibly also decomposition, mineralization, immobilization, or soil organic matter turnoverPollinationFruit-bearing trees per unit areaAdditional criteria and measurable indicators that may be applied purely for internal adaptive management purposes if the necessary resources to undertake the required monitoring are available are specified in Table 3- below. Table 3-: Additional Criteria and Measurable Indicators proposed for adaptive management purposes only if necessary monitoring resources exist

## Ecosystem Attributes

## Criteria

## Measurable Indicators

## Diversity

Plant diversitySpecies richness and abundance of pioneer plant species. Species richness and abundance of secondary successional plant species.

Species richness and abundance of " predicted dominant" plant species. Small mammal recolonisation/diversitySpecies richness and abundance of pre-defined small mammal species, namely rodents. Insect diversitySpecies richness and abundance of pre-defined arthropods, namely ants and terminates, and nematodesBird diversitySpecies richness and abundance of mature species. Species richness and abundance of opportunistic species (to be informed by representative guilds.

## Ecological Processes/Resilience

Erosion controlType and severity of erosion (e. g. rills and gullies, terracettes, sheeting, scalding and pedastalling)Mycorrhizae colonisationProportion of root length containing arbusculesA range of target values will be developed for each indicator across the monitoring time-frame. The change in target values will represent the various stages of forest development and maturity towards the target of a self-sustaining state. Importantly, not all indicators will be relevant for all restoration trajectories and associated stages of successional development.

## Evaluation

The intention is for the proposed criteria, indicators and targets to be used to evaluate restoration progress or success. Three strategies exist for conducting such an evaluation, namely direct comparison, attribute analysis and trajectory analysis. Direct comparison involves the determination or measurement of selected parameters in the reference and restoration sites. If the reference description is thorough, a vast array of parameters can be compared, including both biota and the abiotic environment. Such an approach can however lead to ambiguity of interpretation when the results of some comparisons are close and others are not. A key issue therefore is how many parameters must have similar values and how close these values must be before restoration goals are satisfied. The carefully selection of a coherent suite of traits that collectively describe an ecosystem in a comprehensive yet succinct manner would mitigate such a problem. In attribute analysis, quantitative and semi-quantitative data from scheduled monitoring and other inventories are used in judging the extent to which each goal has been achieved. The attributes are typically assessed in relation to the following criteria (although not all are typically applied concurrently): The restored ecosystem contains a characteristic assemblage of the species that occur in the reference ecosystem and that provide appropriate community structure. The restored ecosystem consists of indigenous species to the greatest practicable extent. All functional groups necessary for the continued development and/or stability of the restored ecosystem are represented or, if they are not, the missing groups have the potential to colonize by natural means. The physical environment of the restored ecosystem is capable of sustaining reproducing populations of the species necessary for its continued stability or development along the desired trajectory. The restored ecosystem functions normally for its ecological stage of development, and signs of dysfunction are absent at the time measured (e. g. at 5 year mark – end of Suralco monitoring period). Potential threats to the health and integrity of the restored ecosystem from the surrounding landscape have been eliminated or reduced as much as possible. The restored ecosystem is sufficiently resilient to endure the normal periodic stress events in the local environment that serve to maintain the integrity of the ecosystem. The restored ecosystem is self-sustaining to the same degree as its reference ecosystem, and has the potential to persist indefinitely under existing environmental conditions. Nevertheless, aspects of its biodiversity, structure and functioning may change as part of normal ecosystem development, and may fluctuate in response to normal periodic stress and occasional disturbance events of greater consequence. As in any intact ecosystem, the species composition and other attributes of a restored ecosystem may evolve as environmental conditions change (SER, 2004). However, due to the need for measurable criteria that can be applied in the short- and medium-term, certain of the criteria above have substantial application limitations due to timing requirements, measurability, and their vague nature, potentially resulting in differing expectations of applications. Some of these issues can be overcome via more detailed descriptions and definitions of the criteria. Trajectory analysis is a promising strategy, still under development, for interpreting large sets of comparative data. In this strategy, data collected periodically at the restoration site are plotted to establish trends. Trends that lead towards the reference condition confirm that the restoration is following its intended trajectory (SER, 2004). The Criteria and Potential Measurable Indicators proposed in Table 3-1 would enable evaluation via either Attribute Analysis (albeit only a subset of the full suite of criteria specified above) or Direct Comparison. Attribute Analysis in fact includes elements of Direct Comparison, and a sub-set of the former approach is believed to be best suited to Suralco’s objectives for the index. The future application of Trajectory Analysis may add value to the evaluation process, but current data limitations and the complexity of the approach are likely to present substantial constraints to its implementation. When representing the results of the evaluation, the plotting of the results in comparison to the target values per indicator in graphical form is suggested (see Figure 3 ). The plotting of a band of " acceptability" for each indicator is also recommended, to reflect potential multiple trajectories and manage unrealistic stakeholder expectations of exact achievement of target values. The actual interpretation of the results will be of the greatest importance though. The achievement of the targets within the " bands of acceptability" for a reasonable sub-set of the indicators, which collectively reflect an ecosystem progressing towards a mature and acceptably resilient state, should be deemed to illustrate success, as opposed to all targets being fully and exactly achieved. The selection of such bands and the sub-set of indicators (e. g. 8 out of 10) that must be achieved will be determined in the next phase of development of the index. Figure 3: Example of specific numeric or qualitatively descriptive targets for a particular indicator

## Phase 3: Target Values for Indicators

The following activities are considered to form part of the third phase of the development of the Reforestation Index: Identify appropriate botanical, ornithological and entomological experts on Neotropical forest ecology in Suriname or the greater Guyana area to inform the selection of target values for each indicator; Determine target values for each indicator; Select potential reference sites and assess target values against actual field results;

andSelect " bands of acceptability" for each indicator and the minimum number of indicators for which targets much be achieved.

## SRK Consulting

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## ANNEX 1

## Annex 1: Bibliography

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moist forests (NT0125) http://www. worldwildlife. org/wildworld/profiles/terrestrial/nt/nt0125_full. html

# ANNEX 2

## Annex 2: Floristic description of Moengo Hills

J. J. DeGranville (1994) described forest types in Suriname based on occurrence of plant families and plant species and on habitat. Dry land forest is a forest on well-drained soils, where the canopy is usually closed and 30-40 m high. Sapotacaae dominate in terms of tree species diversity, in general, as well as in the canopy (trees with dbh> 60cm). DeGranville also indicated that lianas are an important element in dry land forest especially in disturbed or instable areas, as well as in areas where more light penetrates on crests, steep slopes and deep valleys. Epiphytes, hemi-epiphytes and parasitic plants are also important elements. Shrubs and herbs typically occur in the under storey mixed with tree saplings and seedlings. Shrubs and herbs, according to DeGranville, can be abundant in clearings, but many typically occur, throughout the forest: Rubiaceae, Melastomataceae, Piperaceae, Flacourtiaceae, Myrsinaceae, Violaceae, Apocynaceae etc. On pioneer plants DeGranville noted that typical of clearings are the Solanaceae and Myrtaceae. Regarding palms De Granville indicated that they are typically adapted to disturbed or secondary zones and areas that are waterlogged or heavily shaded. Palms that can reach the canopy included Oenocarpus bacaba (kumbu), Jessiana batauta, Maximiliana maripa = Attalea maripa (Maripa) Socratea exorrhiza (ingi prasara), but were more often part of the under storey, such as Astrocryum and the smaller Bactris and Geonoma. Astrocaryum paramaca, A. sciophylum, Orbignya spp. can locally dominate the forest under storey. DeGranville also stated that the under storey herbs formed a discontinuous layer in the lower under storey. These herbs were sparser when the vegetation above is denser and concentrated in areas where more light penetrates. These are mostly Marantaceae, Cyperaceae, Poaceae, terrestrial Bromeliaceae, Acanthaceae, and creeping Rubiaceae. A vegetation inventory was carried out in 2006 to gain insight into the vegetation on the bauxite hills in the Moengo concession area prior to mining. The vegetation type, floristic composition, species diversity and abundance were recorded. These hills serve as a reference site for the mine rehabilitation program for the legacy and active mines. The rehabilitation objective at the time was to restore in the mined-out areas of forest/vegetation types to as close as possible to the natural situation before mining. The vegetation inventory provided a good insight into the plant diversity prior to mining, expressed by the number of species and species abundance. During this field study, the term high forest was used when describing the vegetation on the hills which consisted of mature trees higher than 15 meters with not many shrubs in the under storey. In open spaces herbs some Poaceae occurred and also small trees. In open spaces on fallen trees Marantaceae and Araceae were observed. Palms occurred but were not very abundant. The term secondary forest was used when describing the vegetation which consists of a canopy layer at an estimated height of 10-15 meters, with many opens spaces and in the under storey Poaceae, Arecaceae, lianas or where evidence of disturbances could be observed. The results of the study indicated that there are some differences in plant diversity between the hills, but in general the differences are not significant. A difference exists between the diversity of the hill top and the hill slope and that each hill is very different. Disturbances on Sunday Hill and Peto Hill lead to a higher abundance. The hills had about 25 species in common. These species, according to Schulz (1959), had the potential to survive in the struggle for existence. The species occurring on almost all hills that were considered to be used in the planting scheme, based on their abundance and their ability to survive, were Protium polybotryum (Burseraceae) – Tingi moni rode bast and Eschweilera pedicellata (Lecythidaceae) – Bergi manbarklak. The highest number of plant families were found on Jones 1-d. It was expected that in the undisturbed areas at Theresia fadong and Makka the species diversity would be higher than in areas with disturbance. In areas were higher levels of disturbance took place, the higher the number of species due to the favourable conditions for pioneer species. The plant density on the hilltop of trees with dbh≥10 cm was between 300-562 plants per hectare. This was a reference for the number of individual mature trees that should be standing on 1 hectare in so-called " climax vegetation" after a certain time of the applied mine rehabilitation; probably the last stage of successionWhen comparing the 25 species that the hills in the study had in common, with the species found in the rehabilitated areas from the study by Chin et. al. in 1998, then it appearred that these 25 species were missing in the revegetation scheme at the time of inventory was conducted (July 2006). The general vegetation type to be found on the hill tops when undisturbed was high forest with emergent trees above 25 m height. The canopy was mostly closed and layered. Where the canopy was open than shrubs and herbs could be found in the under storey. On most of the hill tops and slopes on the forest floor under high forest conditions were favourable for mosses, ferns, fungi and epiphytes. The forest floor was not covered with a thick layer of organic material and boulders and rocks were visible. In the shadow the rocks and lower tree part were covered with mosses. This situation occurred on Theresia Fadong Hill, Makka Hill and Jones 1-d hill. In disturbed areas the vegetation was secondary forest with many climbers, herbaceous vines and woody lianas. Pioneer species were present in abundanc, notably on Peto and Sunday Hill. The diversity was highest on hills with much disturbance (Peto Hill).

# ANNEX 3