John Eilif Hermansen

Mediating ecological interests between locals and globals by means of indicators. A study attributed to the asymmetry between stake-holders of tropical forest at Mt. Kilimanjaro, Tanzania

Thesis for the degree of Philosophiae Doctor

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Abstract

Communication of ecological and environmental knowledge, values and concerns by means of indicators and indices is now widely accepted and adopted as a part of environmental management systems, results-oriented politics and international reporting and benchmarking initiatives.

The departure for this thesis is the assumption that there is increasing asymmetry in understanding and control of forest ecosystem resources and services between the local, indigenous people as weak actors on one side and the globalized regime of science, international organisations and business as strong actors on the other. A model denoted Mediation of Ecological Semantics and Sustainability (MESS) is evolved as a contribution to the understanding of the meandering process between different kinds of ecology (soft, practical and hard) and environmental sustainability. The model is the basis for the suggested framework for a proximity-to-target forest ecology indicator.

This thesis presents ecological indicators based on a system of communication and mediation that is intended to provide more equity for local interests, and may support democratization and enlightenment. The indicator is supported by a methodology for development of a multi-purpose ecologically-oriented forest management performance indicator system that also includes stronger participation of local people in defining and mediating the value of tropical forests. With the intention of supporting an open and interactive management system, this aggregated and complex indicator, where individual judgements are necessary, can be denoted as a soft ecological indicator. The ingredients of the indicator are selected on presupposition and distinction between the local and the global interests.

Motivation for the construction of the indicator system emerged during a case study of the catchment forest reserve on the southern slopes of Mt. Kilimanjaro. By using data from plant ecological investigation of the forest, an ideal typological indicator (Catchment Forest Ecosystem Mediating Indicator) is evolved. In order to anchor the indicator in systems thinking, a construct referred to as the Balanced Ecosystem Mediation Framework (BEM-framework is proposed.

Preface

A great interest in the ecology, management and destiny of the catchment forests on hill and mountain slopes in Tanzania was wakened in me in 1984, when I had the opportunity to participate on a consultancy carried out by Institute for Natural Analysis, Bø, Norway on behalf of NORAD and the Ministry of Natural Resources and Tourism (Division of Forestry and Beekeeping), Tanzania.

Later, in 1997, I got the opportunity to participate in the multi-disciplinary research project between the University of Dar es Salaam (UDSM) and NTNU on *Pangani River Basin Water Management Research Project.*

Professor Håkan Hytteborn has been my supervisor and collaborator during the field work and preparation of the botanical paper. I am deeply grateful for his support and collaboration.

Together with Mr. Leonard Mwasumbi (Botanical Department, UDSM) and Professor Håkan Hytteborn (Department of Biology, NTNU) we started in 1998 the field work in the catchment forest reserve at the southern slopes at Mt. Kilimanjaro.

I am grateful for excellent support, guidance, field work and collaboration all these years from:

The Pangani River Basin Water Management Reseach Project organized by Institute of Resources Assessment (IRA) at UDSM and represented by Professor James O. Ngana, and Professor Terje Simensen and Mr Knut Stenberg at NTNU.

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Trondheim, September 2008

John E. Hermansen

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Contents

”*One of the fundamental prerequisites for the achievement*
of sustainable development
is broad public participation
in decision-making”
UNCED (1992) Agenda 21. Chapter 23

1 INTRODUCTION

This section discusses the motivation for and relevance of the thesis, the main research questions, presents the papers attached to thesis and the main contribution of the thesis work.

1.1 Issue

The motivation for this thesis is the idea and contention that there is an increasing asymmetry between local people and the globalized community regarding control, influence and definition of local forest resources on which the local people are depending for subsistence, and that the mediation and negotiation of nature-society relationships weighs unfairly against the local people.

The epistemological grasp in this study to handle the global versus local dimension and the people versus nature dimension, is to allocate the local understanding of forest and fair control regarding local forest resources to the ontological sphere and the scientific ecological acceptable forest management to an epistemological sphere (Hermansen 2006).

Local people have to reorient the basis for arguing and struggling for their naturally given rights to resources from just using the denotation *rights* to elaborate on *legitimate interests* in the same resources as other stakeholders.

To illustrate and convey a discussion on the mentioned issues, a case based on a study of the forest structure and biodiversity of the moist, montane forest at the southern slopes of Mt. Kilimanjaro, Tanzania, has been evolved. The forest is managed by the Catchment Forest Project of the Government of Tanzania, and has for many years been under pressure from serious encroachment (Hermansen *et al.* 1985, Lambrecths *et al.* 2002). One of the purposes of the field investigation inventory and plant ecological measurements was to explore the possibility to generate an ecological indicator that is scientifically acceptable and likewise fair and understandable to the local society. Especially the definition of forest ecosystem resources in terms of ecological services and goods and how mediation between nature-society can be understood, is addressed in the suggested indicator methodology.

Mt. Kilimanjaro, as a location on our planet, is an exceptionally conspicuous and symbolic site not only because it is the highest mountain in Africa, but also because the Uhuru peak is the political symbol for Tanzania’s independence from colonialism. The mountain is also located in the middle of the World just south of equator and on the meridian passing through the ancient cultures of Egypt and Middle East. Walking up through the lush rain forest and tracking the summit of Mt. Kilimanjaro is an adventure of world class, and now the famous ice cap at Kibo also has become iconic due to climate change and the fast melting process; really a site for *globals* (Hermansen 2008c). Thus, of course, the forest is not only a centre for the local society, but the forest is also a centre and focused spot for the global community regarding ecological concern and experience.

But, what about the *locals* – the Chagga people – in these days where the globals have captured the mountain? Historically the Chagga and Masai people have already more than 150 years experience regarding globalisation, which may be metonymy for the locals experience of the previous watchword civilization, by the enforced sharing of their native ground and resources with colonialist and missionary movements even supported in the Article 6 of the Berlin Conference on Tanganyika in 1885:

> *"All the powers exercising sovereign rights or influence (……..) shall, without distinction of creed or nation, protect and favour all religious, scientific, or charitable institutions and undertakings created and organised for the above ends, or which aim at instructing the natives and bringing home to them the blessings of civilianization" ….."Christian missionaries, scientists and explorers, with their followers, property, and collections, shall likewise be the objects of special protection"* (Cited from Leonable-Bart *2006:5)*

The final and serious result of the asymmetry and increasing globalization, discussed in this thesis, is the termination of traditional experience and control over local forest resources by the locals. How could local participation then be accomplished? A shared control based on symmetry requires that the two sides or interests are capable of defending their future by making and managing an arena for mediation and negotiation of their interests.

The purpose of this work is to explore and discuss how communication by means of ecological indicators can be evolved in order to create a more unified understanding of ecosystem resources, possible endangered ecosystems, and attitudes to environmental management of ecosystem resources or nature management and stewardship between the ecological oriented corps of global and international institutions and professionals, and local, native people directly depending on ecosystem resources. Müller and Lenz (2006) address the problem that ecosystem theory and environmental practice and practitioners of ecological indicators have been separated by many factors and frontiers, and they support that linkage should be closer and the communication better.

The importance of local approach to ecosystem management has been addressed on global policy level by UN and other bodies many times including the World Commission on Environment and Development (WCSD 1987) and Agenda 21 from the Rio Summit 1992 (UNCED 1992) and recently confirmed by GEO4 (UNEP 2007).

Studley (2007) addresses rather directly the need of local approach ecosystem management and he underlines the challenge of meeting the steep decline of virtually all aspects of diversity by showing that the three interacting and interdependent systems of indigenous knowledge, biodiversity and cultural diversity are all threatened with extinction.

Scolte (2000: 15-17) provides a classification of several broad definitions of globalization, which are further discussed in Najam *et al.* (2007: 4-11), where not only internationalization and liberation are deliberated, but also globalization as process of universalization, westernization and deterritorialization. The very serious consequences for local people especially in developing countries are that cultures and local self-determination are destroyed in the process in addition to the loss of territories.

This thesis is a contribution to the idea that a common understanding by the globals and locals regarding the definition of forest resources and the possibility of developing instruments for mediating and negotiating interests between parties can be done by ecological indicators.

1.2 Research topic

The main assumption is that ecological management of tropical forest as understood and expressed in a scientific and global perspective is not possible to reconcile with local management by native people based on their traditional knowledge and their understanding of the use of these forest resources. This is due to two arguments:

1. The two levels can not be reconciled because the communication between the two levels, do not function due to the great differences of theoretical and practical understanding of the forest as ecosystem and resource.
2. In addition the distribution of power and influence in the relationship is asymmetric. Local people lose their independence in ontological sense because they lose their rights. But they lose also their epistemological position because of scientification and increased requirement of quality of the knowledge production from the global position dominates more and more over the local position for knowledge production.

Globalization will thereby plunder the local people's control and beneficial rights over their traditional resources and their understanding of the natural system, which in a globalized language is called the ecosystem of moist, montane tropical forest, which ecosystem services they are depending of. The principal starting point for this work is further:

1. That it is necessary with a modern scientific understanding also of the forest ecosystem at Mt. Kilimanjaro in order to achieve a sound and sustainable management both in a global context/scale and a local context/scale, because the forests today are exposed for much greater pressure than in the past. Due to population growth and a more or less wanted transformation to modern life (including development of relationship to global society, education and increased well-being and well fare) local insulation is not any longer possible.
2. That the world community have accept local peoples rights to use and decide over their resources (cfr. many UN conventions on people's rights and sustainable development including the principle of "people's participation"), but it still remain to find proper measures for this kind of cooperative solutions.
3. That peoples traditional rights must or can be taking into account regarding their understanding and their possibilities to be able to participate in developing an ecological based management that correspond with their needs and interests.

From this position the aim of the study can be refined to analyse how scientific and local environmental knowledge can be developed and how the use of ecological indicators which comply with scientific quality on one side and usefulness, relevance and fairness for local people on the other side, can be designed.

As a measure for better communication between the global and local level, a communication model which includes ecological indicators that may serve the need for measuring the relevant ecological qualities of the forest, should be developed. The model should increase the transparency in the communication and decision process between the stakeholders both from local and global level, and connect science with local experience.

1.3 Outcome and structure of the thesis

The thesis work is a cross-disciplinary effort structured by soft system thinking, and includes field work in the forest at Kilimanjaro from 1988 to 2005, and collecting of information and material on forest management issues in Tanzania in the same period. The results are presented in the five papers included in this thesis. Material and results presented in the papers are partly integrated into this main text. Paper IV is dealing directly with the plant ecological field work in the forest and presents the results on forest structure and composition.

The other papers explore the context, concept and construct of the Balanced Ecosystem Mediation (BEM) Framework and the general proximity-to-target indicator Ecosystem Mediating Indicator (EMI), the Forest Ecosystem Mediating Indicator (FEMI) and specific Catchment Forest Ecosystem Mediating Indicator (CFEMI)

1.3.1 Outcomes

Paper I. From colonial to stakeholder rule (regime) – Perspectives on the forest management at slopes of Mt. Kilimanjaro, Tanzania
The paper presents historical and present facts about the administration and management of the forest at the southern slopes of Mt. Kilimanjaro including some facts and assumption (generalizations) about the Chagga people and community relationship of the forested area and the administration of forest in Tanzania. Especially the transformation from colonial, thereafter a centralized governmental and ideological forest management policy, and to recent participatory community based local forest management policy and stakeholder oriented approach. The paper provides material to the forest management context of the indicator system, and indicates the practical circumstances for application of the suggested mediating indicator.

Paper II. Mediation of tropical forest ecological interests through empowerment to locals
The paper describes and discusses the global and local position to ecology and the asymmetric position between the two levels based on both an epistemological and ontological position for development of ecological knowledge and transformation of this information to an eco-indicator system that is fair and equal understandable for all parties involved. A model for Mediation of Ecological Semantics and Sustainability (MESS) is presented. The model is a modification of the industrial ecological mediation model launched in paper III. Theoretical resources from the Actor Network Theory (ANT) are part of the Balanced Ecosystem Mediating (BEM) Framework that is evolved.

Paper III: Industrial ecology as mediator and negotiator between ecology and industrial sustainability (Hermansen 2006)
This paper outlines in the context of scientific ecology and industrial ecology, problems related to power connected to defining and owing the terminology of ecology, moving and relocation of the term and field of ecology, including the diversification of ecology into soft, practical and hard ecology depending on theory, methods and application of ecology. The paper also suggest a model for mediation and negotiation between nature (the ecological side) and culture (the societal side) in order to promote development of sustainable industrial practice. This work can be transformed to and be regarded as analogy to the development and promotion of sustainable use of forest (as in the case of Mt. Kilimanjaro). Further this paper briefly outline the requirement for a diversification of ecology in order to promote ecological integrity and adjust ecological knowledge to be accepted and suitable for negotiation on a nature versus society, or science versus management context.

Paper IV: Structural characteristics of the montane, moist forest on the southern slopes of Mt. Kilimanjaro, Tanzania
The paper presents the results of the plant ecological study in the context of catchment forest. Field methods for measurement of ecological properties relevant for catchment forest management are discussed and applied. The methodology is assumed to be consistent with the overall goal to develop an ecological description of the forest that is scientific acceptable and

also useful and understandable by non-scientist and non-foresters belonging to the local people. The intention of the field methods is then not only an instrument for ecological registration, but also an instrument which facilitates increased ecological awareness and learning, ecological integrity and basis for negotiation between locals and globals and between nature and society.

Paper V: Forest Ecosystem Mediating Indicator. A pilot scheme from the forest reserve at Mt. Kilimanjaro, Tanzania
The paper outlines theory and methodology of the BEM Framework and how the framework can be used in the mediation and negotiation between locals and globals, ecology and natural resources, and between nature and society. The proximity-to-target indicator (EMI, FEMI and CFEMI) serves at the mediating agents. CFEMI, as practical example is constructed on the plant ecological measurement applied in paper IV. The article present the main theoretical and practical contribution connected to this thesis work.

1.3.2 Contributions

The contribution of thesis work consists of four elements which include methodology development, creation of a theoretical conctruct for ecological mediation, development of a forest ecological proximity -to-target indicator and a plant ecological forest inventory connected to the catchment forest management concept. The contributions are all intended to support sustainable forest management and local participation. Due to the overall goal of being an arena for mediation and negotiation the result of the study may be denoted a *methodological preceptive* construct.

First, the methodological construct on how different concepts that are supporting or addressing different contexts for sustainable and participatory forest management was substantiated and evolved.

Second, from contexts, concepts and exploration of how abstract theoretical work can meet the need for ecological communication, two frameworks (models) underpinning ecological communication was evolved:

a. Mediation of Ecological Semantics and Sustainability (MESS)
b. Balanced Ecosystem Mediation Framework – (BEM-framework)

Third, the appurtenant indicators were developed and applied on forest data from Kilimanjaro:

a. General Ecosystem Mediating Indicator (EMI)
b. Forest Ecosystem Mediating Indicator (FEMI)
c. Tanzanian catchment forest management specific Catchment Forest Ecosystem Mediating Indicator (CFEMI).

Fourth, the development of the plant ecological field inventory methods for measuring forest structure and composition for meeting the needs for ecological monitoring and management of tropical forest.

2 Research methods

The purpose of the study is to construct a mediation framework and local proximity-to-target indicators based on empirical ecological research. The multidisciplinary approach requires a research model where several elements are kept together and a soft system engineering (Haskins 2006a) construction is selected where the theoretical resources for outlining context, concept and construct are joined together. There is now sharp border between the different building blocks of the research model, and between methods and parts of the underlying theory for the construct, which then implies that the research model is in itself a methodology for evolvement of ecological mediating indicators. The result of the methodological approach may be denoted *methodological perceptive* due to the guidance it may offer for evolving frameworks for mediation and negotiation.

2.1 Research model

The first thought about this work was about how to understand the forest better in catchment forest management perspective. From this initial thought the work started to build a methodology for shaping a contribution to the ecological indicator literature. The question about how to combine forest ecology and the interests of people at Kilimanjaro, and develop theory around the interchange between ecology and people became the challenge. To build the theoretical network relating to the suggested ecological indicator approach, a research model based on Davis (1966: 27) was selected (Figure 1).

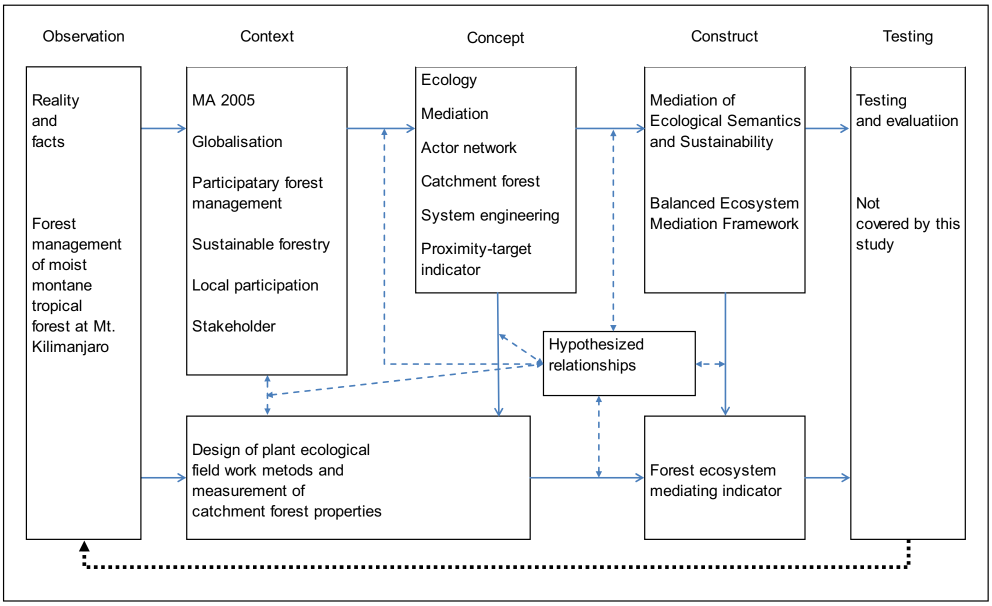

Figure 4. Research model

The initial observation comprise realities and facts about the status, need and constraint about the forest quality and forest management especially connected to South Kilimanjaro Catchment Forest Reserve and Tanzania in general.

To explore the context for new forest management trends both recent global and Tanzanian initiatives were addressed. From context to the construct of mediation framework certain concepts both connected to ecological theory, mediation between humans and human institution on local and global level, and between nature and society are required.

Recapitulated material from the observation, context and concepts blocks are joined together in the constructed mediation frameworks by using soft system thinking.

The forest plant ecological study was initiated by the need for better methods for analysing the forests catchment properties by means of easy accessible measurements methods according to an interchange between experiences from field work and evolvement of context and concepts. Aggregation of the results from field work emerged to the presented indicators system as a parallel to the progress of the mediating frameworks.

The block *hypothesized relationship* illustrates the internal process in the research model for the efforts of continuing search for relevant connections and finally for useful constructs and output from the study.

This study do not comprises testing and evaluation of the suggested mediation framework and indicator, but it is recommended to do as further work.

2.2 Theoretical resources

The study is a multidisciplinary approach composed by five separate articles which should both explore the societal aspects and plant ecological aspects for construction of an ecological indicator which then could be a common instrument for mediating knowledge about tropical forest acceptable in a scientific context and fair and applicable for local people.

The thesis applies theoretical support from several fields and resources divided into the following categories:

1. Context which aims to create the understanding
    a. of important global initiatives, ecosystem services and the framework of sustainable development, globalization and empowerment of the stakeholder position within management, and
    b. the change of forest management from centralized and governmental administration to increased local participatory and community based forest management.
2. Concept which provides theoretical input or tools for the evolvement of the constructed MESS model, BEM framework and the mediating indicators, including the concept of the present forest management system (Catchment Forest Project)

2.2.1 The system perspective

The main methodological approach is a conceptual reasoning built on theoretical elements from different disciplines with a certain anchoring of the management of the forest – human relationship connected to the tropical montane, moist forest at the southern slopes of Mt Kilimanjaro, Tanzania. The complexity of forest ecosystem, the complexity of local society and stakeholders, and global stakeholders and the interaction between the ecological and human processes, makes the development of indicators especially challenging. Complex and constructed indicators or indices appear as quantitative measures and they are also based on quantitative observation and data, but the context and theoretical construction is depending on a qualitative framework. System thinking and systems engineering may serve as a methodology that can assist in combining and binding qualitative and quantitative arguments and data together and then contribute to build the complete model of the framework for the indicator (Asbjørnsen 1992, Haskins 2006b). Due the meandering character of the mediation and negotiation across the interface between the different elements and subsystem, and the use of application of assessment judgement and estimation the indicator system is a soft system (Haskins 2006a, Mendoza et al. 2006).

2.2.2 The actor perspective

The societal aspect is differentiated in the globals and locals and the ecological aspect is differentiated in ecology as science and nature as framework and reference for human existence. In addition the framework and logic for construction of an ecological indicator that should meet the aspects mentioned above must be constructed. The underlying theoretical framework to connect these very different epistemological approaches together (including humans and non-humans), which is necessary in order to work out the multidisciplinary introduced above, together is inspired by the Actor-Network-Theory (ANT) developed by Bruno Latour and Michel Callon during the 1980s and developed further by Latour and others during the 1990s and ahead more directly applied on the human-nature relationship in an ecological – environmental crises perspective (Latour 1993, 2004, Law and Hassard 1999, Sørensen 2004, Hermansen 2008b).

2.2.3 The ecological perspective

The next challenge is to manage to explore ecology or scientific ecology in a way that makes it possible to differentiate *ecology* so it can be scientific acceptable, and understood and useful by the locals. Shrader-Frechette and McCoy (1993) and Shrader-Frechette (1995) and their approach to ecological integrity and differentiation of ecology into soft, practical and hard ecology is a possible entrance to an ecological approach that can work as an mediator between the two position between science and local.

Ecology is rather distinct and lucidly defined when it comes to theory and research methods within the different sub-fields of ecology, but ecology has also became a major part of the political, social and ethical terminology and discourse, and thereby been a victim for a flora of different connotations which will be discussed in the theories. Bruno Latour and Kristin Shrader-Frechette address differences in interpretation within the ecology concept and discuss various implications. Latour (2004) looks at the general political aspects of the ecology concept, while Shrader-Frechette discusses various interpretation of ecology in relation to nature management and conservation (Shrader-Frechette and McCoy 1993) and ecosystem integrity (Shrader-Frechette 1995). Hermansen (2006) tries to combine these two concepts into a meandering and negotiation model between nature represented by ecology and society in order to construct industrial sustainability. In principle the same model can be adjusted and applied on using ecological indicators as mediator between ecology and sustainable forest management.

The study is exploring the strength in a case study that combines various single studies with different methods depending on the character of sub studies. The overall methodology of this work is to approach ecological management and communication dilemmas by combining theoretical reflections on ecology, global and local level for understanding of ecology and then combine results from this discussion with experience from a plant ecological study of the forest. Usually natural science research is based on a reductionism, also much of the ecological research is based on this paradigm, but "*We cannot reduce the biological,* *behavioural, and social levels to the lowest level, that of the constructs and laws of physics. We can, however, find constructs and possible laws within the individual level*" (Bertalanffy 1968: 49).

In doing interdisciplinary research the communication and transfer of information must passes some barriers and permeability this interface is crucial for the quality of the result on system level where the different approaches are considered to be the sub-element.
This study is meant to be consistent within a knowledge conceptual system where the investigated issues are not explained on a reductionistic level (plant ecological inventory) or social anthropological or social science level, but on a level of perspectivism. The possible usefulness in improving understanding, unity and consensus is important. The question of validity is even more important and difficult changing between quantitative (ecological variables, resource value variables) investigations and qualitative (interpretation of perception and communication of knowledge) interests and norms, see more in Kvale (1997: 158). This study is basically a proposal for a multidisciplinary methodology and the question of validity is mainly a discussion about communicative and pragmatic validation, often denominated *content validity* (Ringdal (2007: 87).

2.2.4 Indicator perspective

Ecosystem management and use of ecological indicators are instrumental to the universal efforts of sustainable development, which in turn often appears to vary between different regions and societies around the world. Dahl (1996) is discussing the dilemma of measuring the unmeasurable suggesting that macro indicators could be vectors indicators rather than static description of a situation. Transformed to environmental and ecological quality assessment of the forest inventory of this study, we may try to construct a "proximity to target" indicator. Target is then defined as expert judgement for a typology based on model forest plots. The suggested forest indicator system, will due the local and limited function area, can evolve to vector for enlightening and democratization.

To measure ecological and management oriented policy categories, such as for example the wise and sustainable use of forest resources, requires a set of different measurable indicators and data. Some are easily measurable with instruments and metrics, and others by judgement, often value laden along a scale. Performance indicators on social level usually refer to different kinds of reference conditions and values, such as national or international policy targets. Especially demanding, both technically and politically, is the implementation of sustainability performance indicators. Often they are very vague and difficult to follow up and address with responsible authorities or actors.

European Environmental Agency (2007) has defined the usefulness of a proximity-to-target approach:

> *"… concept of environmental performance evaluation is being developed for use in an environmental management system to quantify, understand and track the relevant environmental aspects of a system. The basic idea is to identify indicators (environmental, operational and management) which can be measured and tracked to facilitate continuous improvements. Performance indicators compare actual conditions with a specific set of reference conditions. They measure the 'distance(s)' between the current environmental situation and the desired situation (target): 'distance to target' assessment.*"
> (EEA , Multilingual environmental glossary, Internet)

Proximity-to-target indicators are a type of environmental performance indicator designed for ranking, benchmarking and monitoring action towards some well defined and measurable objectives. The proposed CFEMI is an extension of the concepts and principles from both the macro (societal) and micro (corporate) levels including mimicry of the proximate-to-target indicator from '*Pilot 2006 EPI Environmental Performance Index*' launched by Esty *et al.* (2006).

3 Background

The purpose of evolving the forest ecosystem mediation construct rests on global trends and Tanzania initiatives regarding strengthening participatory forest management, principles for ecological integration, protection of ecosystem services, and indicator theory.

3.1 Trends in global governance towards the position of local participation

One of the perspectives for this study is the recognition of the importance the services the montane, moist forest ecosystems can provide regarding water supply, different forest products and conservation of biodiversity (WCFSD 1999, MA 2005, FAO 2007). There is also a need for appropriate inventory methods, which can also be used by non-scientists. Further, in such inventories a set of indicators should be used, that can mediate the ecological information to and between the different stakeholders (Mendoza and Martins 2006). Which inventory methods in the future could be suitable in such a perspective is of importance. Such methods should be based on general management principles which include strategies for development of indicators for a multi-scaled nature conservation approach (Lindenmayer *et al.* 2006, Vermeulen and Koziell 2002, Van Bueren and Blom 1996)). Indeed the traditional ecological knowledge should also be given its rightful place in the analysis (Sallenave 1994).

As a response on global perspective of status and problem solving of conservation of ecosystem, protection and ownership of biological diversity and measured connected to Millennium Development Goals, some authors are questioning about the influence of local people and arguing for more local perspectives. Vermeulen and Koziell (2002) emphasis that the global consensus is that of wealthy countries, and that biodiversity assessments are based on values, and they conclude:

> *"The principles of the Ecosystem Approach may or may not be an appropriate basis for collaborative approaches to biodiversity assessments, depending in part on whether the CBD can develop and sustain credibility and impetus at local levels. A global set of principles is only one of many potential ways forward – principles rooted in national or local realities could be just as good t bringing multiple biodiversity values into more open debate. (2002: 93)*

Faith (2005) in his editorial on global biodiversity assessment and how to integrate local values and human dimensions argue against Vermeulen and Koziell (2002: 5) especially that

> *"They recommend consideration of biodiversity only in terms of local ecosystem services derived from it, and not as and end in itself. This argument at its extreme suggests the absurd prospect that local values are to exclude any consideration of global values"* Faith 2005:5

Tropical forests are under heavy pressure of exploitation and land use change both from global and local driving forces. Interests in and conflicts over environmental resources are today often understood and discussed in the perspective of a stakeholder. Further a new group of stakeholders are emerging which includes consumers, professional and academic organizations, community and environmental groups, and even surrogate stakeholders for interests not traditionally represented like the planet's biosphere, the world population and future generations (Elkington 1998: 166). In many cases the global oriented driving forces are the strongest ones which in turn results in loss of influence, control and access to the traditional forested areas and resources for the local, native people and societies. Stakeholders comprise local community of affected people with traditional beneficial rights, but also the global community of ecological science, management and environmental concern. Mendoza and Martins (2006) concludes that

> "*Stakeholders or decision makers must be able to participate and contribute actively to modelling – from identification of model elements, formulation of relationships, and all other model components, including the actual decision-making process. This call for a more transparent, simple, and accessible participatory modelling paradigm and process."* (2006: 19)

Forestry studies and assessment of forest resources have to a large extend been mono disciplinary in their approach depending on the defined and usually relatively limited purpose of the study. Well known are industrial forest inventories that are mainly assessing the forests in terms of commercial timber production. An ecological approach to forest studies on the other hand tries to consider the forest not only as a resource for the forest industry, but its total value, also for organisms not directly of economic value. One important objective of plant ecological studies of forests is to mediate scientific acquired ecological information and knowledge about the ecological quality of the forest to stakeholders. Robertson and Hull (2001: 971) discuss and argue for "the term *public ecology* to draw attention to the public decision making context to which conservation knowledge is applied". Many forest ecosystems and forested areas are under special concern due to their importance for local and regional ecosystem services and as constituents of well-being.

The methodology of this investigation is intended to contribute to enlightenment and support dialogues and a discursive approach to management between the affected local people – the ontological approach – and global and scientific interests – the epistemological approach – as outlined by Hermansen (2008b).

3.2 Forest management in Tanzania

Mainland Tanzania has according to Blomley (2006) one of the most advanced community forestry jurisdictions in Africa, and Participatory Forest Management (PFM) has become the main strategy of the forest policy. He states that among the lessons learned is an increasing awareness of the importance of local forest users and managers and he espouses decentralized forest management schemes. The indicator system suggested in this paper is devised to support these efforts.

New national forest polices over the last 15 years have as a goal to improve the effectiveness and promote local responsibility towards a sustainable forest management practise (Hermansen 2008a, MNRT 1998, 2001, 2006) with the development of criteria and indicators for sustainable forest management in Tanzania (MNRT 1999). Local participatory forestry (Blomley 2006), forest management and democracy are all important issues and it not easy to find ways to transfer enough power and security to local communities and devise sustainable and effective local forest management (Wily 2001). Global initiatives connected to fair trade strongly support the strengthening of local forest management (Macqueen 2006, Macqueen *et al.* 2006).

Foundation of the new independent nation in 1961 and introduction of the Catchment Forestry Project (CFP) by the Forest Division of the Tanzanian Ministry of Lands, Natural Resources and Tourism in 1977 resulted in a weakening of the local management and a strengthening of governmental administration and management of the forest. CFP did not manage to handle this forest well, and encroachment, deforestation and fragmentation of the catchment forests increased (Hermansen *et al.* 2005). A team of consultants and researchers (Sjaastad *et al.* 2003) analysed on behalf of Tanzania Ministry of Natural Resources and Tourism resource economic value of the catchment forest reserves and this study provides much information regarding the policy, plans and management of the forests during the last 25 years.

Previously, national forest policy was an integrated part of governmental forest politics, but during the last 20 years forest policy has been more and more oriented towards a stakeholder approach (Hermansen 2008a). Sjaastad *et al.* (2003) has reported and analysed the stakeholder values for the Catchment Forest Reserves in Tanzania including South Kilimanjaro Catchment Forest Reserve

The objectives of the CFP can be summarized to promote the utilization of the forest resources in a sustainable manner, and secure that the three key functions - production of forest goods, water generation and conservation of biodiversity of the forest - are maintained. The following interpretation of objectives forms the relationship between management purposes and ecological contents (Hermansen *et al*. 1985):

> ***Water generation**. Regulation and conservation of water resources and supply in the catchment area; reduction of run off and soil erosion, which is especially important in moist mountain areas.*
>
> ***Gene-pool conservation.** Preventing extinction of rare and endemic plant and animal species in the diverse moist forest; it is essential to maintain biodiversity and keep the genetic potential for ecological and evolutionary purposes and for present and future utilisation of biological forest resources*
>
> ***Production.** Logging of indigenous tree species and supply of other forest products for local consumption and sale.*

Participatory Forest Management (PFM) has become the central strategy of Tanzania's forest policy and the country has one of the most advanced community forestry jurisdiction in Africa (Blomley 2006). The awareness and achievement for more local involvement in forest reserves administrated by the Ministry of Natural Resources and Tourism under the Joint Forest Management (JFM) is also raised, and South Kilimanjaro Catchment Forestry Project (SKCFP) has entered into agreements with several local communities / villages on participatory forest management within the buffer zone of forest reserve (including HMFS and ravines and erosion sentive area beneath the forest reserve border) (Akitanda 1994, 2002).

4 Case: Forest on the southern slopes of Mt.Kilimanjaro

Historically the forestry management of the forest at Mt. Kilimanjaro started under the German colonial time in the 1880s. The forest was then managed by central government. The forest has been exploited by logging with several sawmills operating inside the forest until 1978 when logging was suspended due to overexploitation.

In the colonial 19th century the European settled and started the process of civilization of the local Chagga people. The forest turned from being a traditional resource chamber for wood, food, medicine and most important an everlasting water source for their irrigation agriculture, into a timber and commercial logging area.

The independence of Tanganyika in 1961 was of course a historical and political event where national and local control over natural resources was expected to be transferred to the people and Government of Tanganyika and Tanzania, and that forest management would serve the long term interests of the people. Due to several causes like overexploitation of forested land, lack of adequate forest management competence, strong interest from the global scientific community, increased focus on environment and sustainable development in a global context, the local influence, control, and definitions of the management issue and agenda are restricted.

Today, the value of water resources generated in the forested area, which provide water for agriculture, hydropower, industry and household for hundred of thousand people, is probably the significant goods from Mt. Kilimanjaro in addition to income from international tourist. Foreign currency is very much appreciated income for Tanzania.

In 1941 a forest strip denominated 'The Half-mile forestry strip' (HMFS) due to its extend of some 800 m wide, on the border to the inhabited and agrarian landscape at about 1600 - 1700 m asl, was separated from the forest reserve and transferred to Chagga Council for local management. The family farms downhill the forest have been for several hundred years fed by water lead by a large numbers of furrows from the forested area above (Stahl 1964, Hermansen *et al*. 1985, Newmark 1991, 2002, Kivumbi and Newmark 1991, Ngana 2001, 2002, Bart *et al.* 2006, Tagseth 2006, 2008).

During the 1980s the international process of introducing the concept of sustainable development, the UN Rio-declaration on Sustainable Development, Declaration of Forest, the principles of people participation became stronger and when rounding the millennium the management of the HMFS is again partly transferred to local administration and responsibility including influence on other forest resources on the southern slopes of Mt. Kilimanjaro (Mariki 2000, Akitanda 2002, Sjaastad *et al.* 2003).

Foundation of the new independent nation in 1961 and introduction of the Catchment Forestry Project (CFP) by the Forest Division of the Tanzanian Ministry of Lands, Natural Resources and Tourism in 1977 resulted in a weakening of the local management and a strengthening of governmental administration and management of the forest. CFP did not manage to handle this forest well, and encroachment, deforestation and fragmentation of the catchment forests increased (Hermansen *et al.* 1985). A team of consultants and researchers (Sjaastad *et al.* 2003) analysed on behalf of Tanzania Ministry of Natural Resources and Tourism resource economic value of the catchment forest reserves and this study provides much information regarding the policy, plans and management of the forests during the last 25 years.

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Traditional water use and water conflicts in the Kilimanjaro area are covered by a number of works which also outline and analyse the catchment forest reserve under SKCFP (Newmark 1991, Ngana 2001, 2002, Akitanda 2002).

Akitanda (1994), Mariki (2000), Øyen (2000) and Tagseth (2000, 2006, 2008) present historical, updated information and analyses of how people and villages are handling the water issue.

4.1 Inventories and assessments of the forest

Historically forest inventories at Mt. Kilimanjaro can be allocated to two categories. The first one represents industrial forest inventories focusing on volume estimations and quality of the commercially valuable timber trees like *Ocotea usambarensis*, *Macaranga kilimandscharica*, *Xymalos monospora* and *Podocarpus* spp and some few other species. Probably the Jakko Pöyry (1978) inventory was the last one of this type for SKCFP.

The second category represents registration of plant species often along orographic gradients based on botanical, ecological or management oriented perspective. Many of the former works were floristic and qualitative with the purpose to register the biodiversity and to demarcate vegetation zones (Pike-Jones 1948, Hedberg 1951, 1955, Salt 1954, 1955, Wood 1965a, b).

In recent years more qualitative works have been published which also address human impact and management issues (Bjørndalen 1991, 1992, Hemp 2001, 2002, 2005, 2006a, b, c, and Hemp and Beck 2001). Relatively few quantitative botanical studies have been carried out in the forest belt at Mt. Kilimanjaro and published.

The period from 1980 to 2005 can be divided in two phases. The first is about the work for raising the necessary concern and approach for a new multipurpose management strategy, and the second from 1995 is about how an effective management should be possible to implement and implententing Participatory Forest Management (PFM) and Joint Forest Management (JFM).

During the 1980's it became clear that a more powerful action was necessary in order to implement the management strategy for the catchment forests at hill and mountain slopes, and the collection of information was increased (Hermansen *et al.* 1985). The Catchment Forestry Project published in 1994 a selected, annotated bibliography on biodiversity (Howell 1994). The literature on the concern for proper catchment forest management and documentation of biodiversity increased during the 1990s. Hermansen *et al*. (1985, 2002), Bjørndalen (1991, 1992), Newmark (1991, 2002), Katigula (1992), Lovett and Pocs (1992), Lovett and Wasser (1993), Malimbwi *et al.* (2001) and Ngana (2001, 2002) describe and discuss ecological and catchment aspect and forest management of the forest of Mount Kilimanjaro. Kashenge (1995) wrote a management plan for the period 1995-2000 approved by the Forestry and Beekeeping Division.

4.2 Previous studies and inventories suitable for multi perspective approach and supporting integrating decision making

From 2000 and onwards several works have been published in which the inventories and perspectives are better integrated with the principles of catchment forestry. Also, during the recent years several studies have been carried out with the aim to quantitatively describe the Kilimanjaro forest and the distribution of the tree species that make up the structure of the forest.

Malimbwi *et al.* (2001) evolved and carried out an inventory under the new system of collaborative forest management which includes reliable information on forest standing stock for rational decisions in management and proximity to the interests of local community. Hermansen *et al.* (2002) presents preliminary results from inventories of the structure of forest plots. Yanda and Shishira (2001) analyse changes in the forested area and resource utilization and William (2003) is reporting a case study on the implications of land use change on forests and biodiversity from the HMFS at Mt. Kilimanjaro.

Hall (1991) investigated the method of multiple-nearest-tree sampling in an ecological survey of catchment forest in East Usambara, Tanzania. Malimbwi *et al.* (2001) launches inventory and monitoring methodology which are aiming to meet the need for information under the new system of collaborative forest management, rational decisions in management of forest resources. William (2003) has examined the land use changes in Mweka and Lyasomboro villages in Moshi Rural District and how these changes have affected resource use, forest cover and biodiversity in HMFS based on aerial photos from 1952 and 1982.

Recently A. Hemp has published a series of articles based on fieldwork on Mt Kilimanjaro about *Erica excelsa* (Hemp and Beck 2001), ecology of pteridophytes (Hemp 2001, 2002), climate change (Hemp 2005) and contributed to an OECD report about climate change (Agrawala *et al.* 2003). Hemp (2001, 2005, 2006a) and Agrawala *et al.* (2003) has also systemized the vegetation in main vegetation units along the altitudinal gradients. This comprehensive field-based article serves the need for information about biodiversity as well as ecological factors including encroachment, forest and heath fire and possible climate change. Hemp (2006b,c) also discusses long-lasting influence and disturbance of both human and large animals on the patterns of diversity, endemism and vegetation belts. He suggests that the low rate of endemism of the lower altitude forest compared to the Eastern Arc Mountains, may result from destruction of forest rather than the relatively young age of the Kilimanjaro mountain. A large multi-purpose project mainly using remote sensing techniques has recently been published (Bart *et al*. 2003/2006) and another study of soil characteristics by Schrumpf *et al.* (2007).

Huang *et al.* (2003) carried out a study in the forest reserve of the neighbouring area of East Usambara Mountains, Tanzania of the effects of tropical forest structure and species composition on the species diversity by using data of 279 inventory plots. They found that species diversity was significantly influenced by structure and composition of forests as it account for a great number of habitats.

Madoffe *et al.* (2005, 2006) has presented on internet a baseline on selected forest reserves from a forest health monitoring project in the Eastern Arc Mountains of Kenya and Tanzania. A methodology, which includes 43 permanent plots, is developed in order to present three main indicators of forest health (mensuration, visual crown ratings and tree damage) where collected to proved baseline information on the forested areas. No plots are from Mt. Kilimanjaro.

4.3 Present field study on forest structure and composition

Forested areas on mountain and hill slopes are considered to play a crucial role for water generation both regarding water volumes, quality, spatially and seasonally distribution. A specific management is under development to include a multi-purpose management built on the recognition that the forest values can be determined both with biological, hydrological and forestry indicators.

Present study is built on results acquired from a subproject under the multi-disciplinary research co-operation between University of Dar es Salaam and The Norwegian University of Science and Technology on water management in Pangani river basin (Ngana 2001, 2002. The purpose of the study was to investigate the composition and structure of the forest on the southern slopes of Mt. Kilimanjaro in the context of catchment forest. This includes registration, description and analyses of the structure and biodiversity of vegetation.

We developed a methodology for description of forest structure and composition along altitude gradients. By analysing plots along an orographic gradient we describe distribution and correlation between several variables both from a perspective of biodiversity and water management.

The study was a registration and analysis of the tree species and an analysis of the structure of the tree layers and of the shrub and field layers. However, only the tree layers are treated here. Preliminary analyses showed distinct difference between plots in the HMFS and in the forest higher up. Thus, in the further analyses these areas were treated as two strata.

5 The construct of the BEM Framework

The construction of the indicator is built on a pre-understanding of communication as an instrument for mediation and negotiation of knowledge and interests, and that these processes are integrated and accepted as fundamental for further development of the context where FEMI will contribute. In section 5.1 is the conceptual system for mediating and negotiating between nature and use of forest resources towards sustainable forest management presented (Hermansen 2006, 2008b). The Balanced Ecosystem Mediation Framework is meant to be an operationalization of this general mediation model, where the indicator serves as mediator.

Technically, most environmental indicator systems are designed within an open system concept which includes conceptual, normative and operational elements. The notion of a system often encompasses "*a combination of interacting elements organised to achieve one or more stated purposes"* (Haskins 2006b), and could be an assemblage of elements constituting a *natural system*, a *man-made system*, an *organizational system* or a *conceptual knowledge system* (Asbjørnsen 1992). The system approach applied can be denoted *soft system* (Haskins 2006a) due to interchange of contexts and concepts are the issues that give momentum the mediation process while the indicator is instrumental to the process.

An ecological indicator system aiming to be a management tool can be defined within all these four classes of systems and merged into an overall communication system where the indicator and the different circumstances around the indicator become elements in the system. The challenge is to design and understand how the interaction across the boundary interfaces between the elements, the subsystem and eventually the environment outside the system boundary, influence and bring the system into being. Systems thinking is an underlying concept used to assist in combining the ecological and social elements in the development of FEMI such that the indicator moves closer to a management and stakeholder approach.

5. 1 Model for Mediation of Ecological Semantics and Sustainability (MESS)

Requirements to a fair and democratic oriented model for ecological communication includes as a minimum that the model is open, suited for deliberation and gives the opportunity for stakeholders to reflect on how ecological knowledge is gained and controlled. Figure 2 illustrate a model for discursive handling between ecology and society where different ecological approaches are respected and suitable for communication between participants in the discourse where there exists a great difference in background conditions and asymmetry regarding the possibility to obtain necessary power in resource conflicts and global public discourse. Practical ecology represents here the daily and regular communication of an intrinsic and ontological character. Hard ecology is representing the exotic communication which is strongly epistemological defined scientific ecology and soft ecology is representing a strong and traditional understanding or belief of how the ecosystem services are part of a holistic and mythological approach. It is the tacit base for an ontological approach for local people and is often the ultimate position for explaining the cause and mechanism behind the appearance of practical ecology. The explanation of practical ecology can be moved towards soft of hard ecology. It is of course also possible increase both a soft and hard ecological understanding. Local people that have mainly been understanding the ecosystem services and ecosystem description by using a practical and soft ecological, should be more involved in the new understanding of ecosystem services and management coming from the hard ecology.

The model represents a structure that can help different shareholders to understand the difficulties of ecological communication between different epistemological approaches and ecological practises. Translocation of knowledge involves loss of information and accuracy and depending on interface or membrane between the sub-elements in the communication system. One way arrows represent an interface like a semi-permeable membrane where the useful information goes in one direction, while the two way arrows represent permeable interfaces. In this tapestry (image) transfer of information between the scientific ecology system and experienced social practise can be managed.

The purpose of ecological indicators in this context is to function as a mediating and negotiating agent between the nature represented by ecology and culture represented by society (including the local community and international ecological and environmental concerned society of scientist, politicians, NGOs and citizens in general), and thereby as a kind of consensus indicators in the category of practical ecology are the most fair and effective indicators to ensure a proper protection of ecosystem with a frame of the local community and proper and sufficient scientific quality of the indicators.

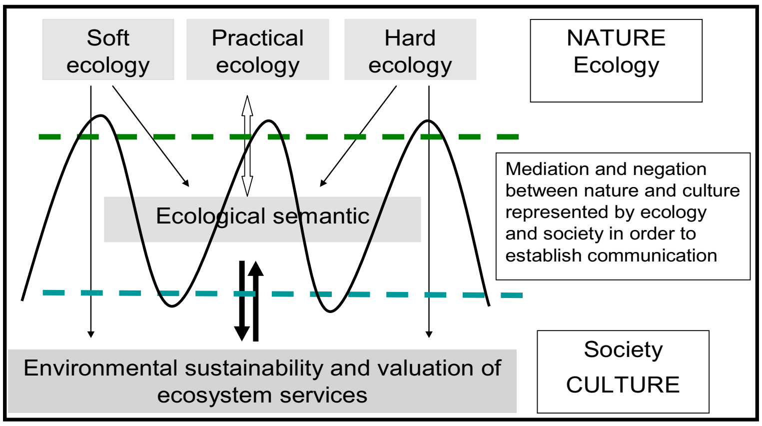

Fig 2 The model shows the semantic and rhetoric functions of ecological communication as hub or as marked square for mediation and negotiation between nature represented by an ecological approach and culture represented as a society that is very well aware of the great dependence the communities well-being is of the ecosystem services that surrounding environment is providing regarding supporting, provisioning, regulating and cultural services (MA 2005)

5.2 Sustainable forest management

Van Bueren and Blom (1996) advanced the *"Hierarchical Framework for the Formulation of Sustainable Forest Management Standards. Principles, Criteria, Indicators"* (PCI) which challenges many of the aspects relevant for the FEMI indicator system. They suggest top-down oriented hierarchal framework for a forest management system with consistent standards based on the formulation of principles, criteria and indicators for sustainable forest management (Figure 3). In the context of development of FEMI, the PCI system appears to be an expert-oriented initiative that belongs to the sphere of influence and interests of the globals.

In order to create a structure involving the locals and strengthening their interests while supporting dialogue and continuous learning, the PCI framework has been modified. The proposed structure allocates the indicator system a more interactive role, and enlarges the system to a construct that shows an ideal typological symmetric mediation between the locals versus globals, ecology versus nature (resources or ecosystem services), and society versus nature. The new framework is called the *Balanced Ecosystems Mediation (BEM)* Framework (Figure 4).

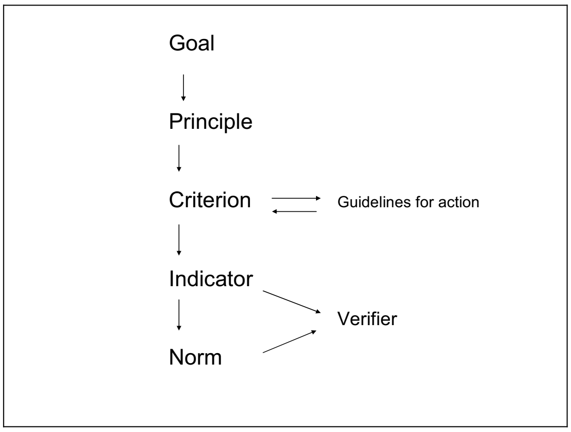

Figure 3. The linear hierarchical PCI framework for the formulation of sustainable forest management standards (after Bueren and Blom 1996: 15)

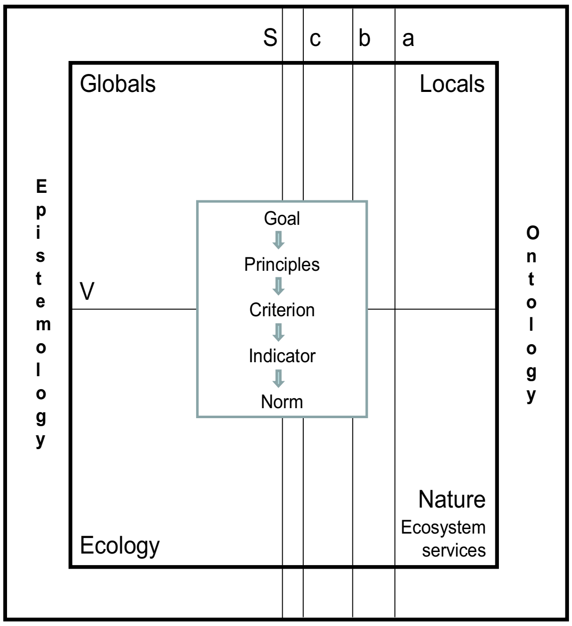

Figure 4. The construct of the Balanced Ecosystem Mediation (BEW) Framework with the two knowledge regimes ontological and epistemological. S and V are representing the ideal typological symmetry (or balance) regarding mediation and negotiation for globals versus locals stakeholders and society versus nature (as stakeholders) respectively. The indicator is here meant to be a Mediating Ecosystem Indicator (MDI).

The transecting lines S and V in Figure 4 represent the ideal symmetric or balanced case based on scientific and normative criteria and arguments. The S should be associated with symmetry in influence between local and globals, and V with values that ecosystems can provide. The vertical lines a, b, and c illustrate different constellations where the position, influence and control by the locals is more or less reduced or lost to the globals. The line **a** shows the situation where the locals are incapacitated and have lost most control over their ecosystem resources; line **b** represents the situation where the locals have managed to participate in forest management; and line **c**, the situation where the locals have substantial influence and control over local ecosystem services.

If *V* is moving upwards the ecological interests and concerns increase with stronger emphasis on protection and conservation, and if *V* is moving downwards, society takes more of the ecosystem services with an increased ecological unsustainability impact and possibly a strong attenuation of the ecological resilience capacity.

The BEM framework should be regarded as an open system where the borders between the elements and subsystem are interfaces where mediation and negotiation can occur between the stakeholders involved. Both mediation and negotiation can take many forms depending on the question discussed or stakeholders (and subgroup of stakeholders) participating in the discourse.

The corresponding influence of how the understanding of ecology (scientific) and nature, and the epistemological and ontological approach, are also illustrated in Figure 4, and derives from the case study work in which the *indicator* was designated to be the core element in the forest management system in order to strengthen the position of the locals. The BEM framework is built on a nature versus culture model presented in Hermansen (2006:90), and discussed further in Hermansen (2008b)

FEMI is the general and theoretical model for the indicator, while CFEMI is intended to be a specific and practical indicator reflecting the complexity of the relationship between the catchment forest ecosystem and local society.

6 Ecological mediating indicators

The *Catchment Forest Ecosystem Mediating Indicator* (CFEMI) is pilot scheme developed on site as a specific ecological mediating indicator. CFEMI is based on experience from an ecological investigation of the plant life in a tropical moist forest at Mt. Kilimanjaro (Hermansen *et al.* 2008) and the conceptual outline of a *Forest Ecosystem Mediating Indicator* (FEMI) and the general *Ecosystem Mediating Indicator* (EMI) suggested and argued for in Hermansen (2008c).

6.1 Purpose and objectives of CFEMI

CFEMI offers a composite indicator of relevant ecological features that can be recognised as essential for catchment forest management; namely the conservation and protection of a specified forested area that serves local people with ecosystem services in a global perspective. Management means to keep and even enhance the forest quality within the area in order to improve water conservation and generation, to protect biodiversity and to serve local people with forest goods.

The overall goal of CFEMI is to contribute to a broad stakeholder-oriented approach (Grimble and Wellard 1997, Elkington 1998, Grimble 1998) to the knowledge and understanding of the forest and to promote an ecologically and socially wise use of the goods and services of the forest, including contributions to:

- reasonable common understanding of status and changes of the ecological conditions in the forest between globals and locals,
- motivating, learning and increasing a management oriented behaviour towards the forest resources,
- meet the requirement for local participation; application of the indicator could vary (e.g. full employment of the concept and indicator system or limited employment mainly showing the large structures in the forest).

Classes of objectives encompass:

- protection of forest ecology quality
- secure ecosystem services from the forest for the local people
- materiality for mediation and negotiation between locals and globals
- increasing local influence, control and competence regarding local resources
- providing of opportunities for interactive learning loops.

The act of creating the indicator encourages mediation of the ecological aspects into a logical structure from goals to corresponding objectives, practical variables, measurement procedure and collection of relevant data.

6.2 Selection of variables and primary indicators

The case of forest management at Mt. Kilimanjaro and the Chagga people as representative stakeholders for local interests is used here as an illustration of the conceptual and practical circumstances of the indicator scheme. CFEMI is proposed as a proximity-to-target indicator meant to work in the context of negotiation and mediation between globals and locals, while strengthening the local interests, influence, control and competence regarding sustainable forest management. The distinction between globals and locals are used to underline the actor perspective of the two paramount stakeholder groups of local society and international organisations, institutions and power structure. Both globals and locals are aggregates of other more specified stakeholders (See Sjaastad *et al.* 2003).

Table 1. Criteria for the selection of variables

Criterion	Description
	ECOLOGICAL ASPECTS
1	Represent important forest physiognomy and biodiversity if trees on a plant are at an ecologically acceptable level
2	Directly associated to ecosystem services (Supporting, provisioning, regulating and cultural services)
	MEDIATION AND LEARNING ASPECTS
3	Easy or intuitively understandably by local people as a relevant description of forest services and goods
4	Support learning processes
5	Supporting learning processes and local participation in selection of indicators, measurement and calculation
6	Support management efforts
	TECHNICAL ASPECTS
7	Easy to measure and calculate
8	Does not hurt the ecosystem

CFEMI should support the management goals for inter alia CFP and MA in a manner that strengthens the influence of local people and mediation between locals and globals. Table 1 gives an overview of criteria for selection of ecological features that could be relevant variables or primary indicators for CFEMI. Appendix 1 shows the complete list and description of the measured variables, units and levels of measurement.

Composition of variables is decided based on the criteria of what are relatively easily accessible. The variables cover important features for the ecosystem services connected to biodiversity and structure where the hypothesis is that the untouched forest has the potential to provide for the demanded ecosystem services such as production of forest goods (e.g. timber, fuel wood, fodder, medical plants), conservation of biodiversity, and water regulation and supply of water of good quality.

6.3 Measurement and data

More information about the ecological study including descriptions of the study area, field methods and discussion is presented in Hermansen *et al.* (2008). The detailed results are measurements taken of individual trees, both the measured variable and the aggregated data, for each of the 54 sites of 1000 sq. m along tree transects Mweka, Kilema and Marangu.

Once the variables were determined, data collection was based on rather simple methods and it should be possible for people with some experience in forestry and forest management to adapt the methods and use them. No advanced knowledge about species and taxonomy, or calculation methods was necessary.

6.4 Determination and calculation of targets

Identifying indicators, assessing possible values, and deciding on targets require both a quantitative and qualitative approach. Based on experience and criteria the target for each variable can be decided. A specific value connected to each target is calculated and partly estimated from average values from the cluster of sites. Table 2 gives an overview over objectives, ecological aspects and categories, indicator/variables, units, average score for all sites within each variables and target for CFEMI (Hermansen 2008c Appendix 2 shows data for each variable and score as percent from target for each site (plot)).

Table 2. CFEMI indicators and target values for ecological aspects.

Ecological aspects	Category	Indicators / variables	Units	Notes	Average	Target
Forest structure	**Tree structure**	Number of stems	no	1	40.6	50
		Basal area	m^2	2	6.0	7.5
		Tree height	m	3	19.2	24
	Leaf cover	Crown width	m^2	4	67.2	84
		Crown width sum	m^2	5	2416	3020
		Crown depth	m	6	11.8	14.7
Biodiversity and water conservation	**Epiphyte cover**	Covering of climbers	class	7	1.5	1.9
		Covering of vascular, lichens and bryophytes	class	7	2.3	2.9
Biodiversity	**Tree species**	Number of tree species	no	8	6.7	8.4

Data are based on the measurement and estimation of 1502 trees within 36 sites (plots) of 1000 m^2. The different targets are set close to the score for well developed stands and approximately 25 percent above average values. All the sites are within the forest reserve. Sites mainly containing more than 50 *Erica excelsa* trees and sites from Half Mile Forestry Strip are not included in calculation of average values and target values. Notes:

1. The number of trees per plot varies between 2 and 89. Overall average number of stems is 41.
2. The sum of basal area per plot varies between 0.1 and 13.2. The overall average is 6.0.
3. The tree height varies between 6 and 40 m. The overall average is 19.2 m.

4. The average crown width per plot (the horizontal project of the crown for each tree) varies between from 10 to 170 m^2. The overall average is 67 m^2. The largest crown is 961 m^2.
5. The sum of crown width for all the trees within a plot. The crowns are merged into each other and will therefore exceed 1000 m^2. The sum varies between 70 and 5450 m^2. The overall average is 2416 m^2
6. The crown depth varies between 7.2 and 16.2 m as average for the different plots. The overall average is 11.8 m. The highest tree crown depth is 39 m
7. Epiphyte cover is estimated by a non-linear classification and the calculated average is the average class for the tree within the plot. Target is set to 25 % above average. Average above 3.0 implies that the average tree has a substantial cover of epiphytes and climbers, which may play an important role for water conservation and retention.
8. The number of species within the plots varies between 2 and 13. The average is 6.7.

The reliability of data differs from variable to variable, and Hermansen *et al.* (2008) contains an outline of the inventory and a more complete discussion of the results. The most exact measures are identification of species, number of trees and basal area which is measured. Tree height, crown and epiphyte cover is estimated.

Calculation and display of results are made as easy as possible by allocating the same percentage value for each variable, and the results from the calculation will reveal which sites are far from the ideal typological state. The model shows both the factual relationship between the sites and a significant difference between them, which also will appear if we look into the data lists.

6.5 Results

The proximity-to-target score for the sites along the three altitudinal transects from lower to upper forest borders at the southern slopes of Mt. Kilimanjaro of Mweka, Kilema and Marangu, is shown in Table 2 and Table 4 shows average values for the sites along each transect grouped into three zones: HMFS, central part and the upper part of the forest reserve. In figure 5 is the results for Mweka transect showed (See Hermansen 2008c for the results for the two other transects)

Table 3. Average CFEMI score group for the three distinct altitudinal zones of the forest along the three transects Mweka, Kilema and Marangu at the southern slopes of Mt. Kilimanjaro. Number of sites is shown within parenthesis.

	Mweka		Kilema		Marangu		Average	
HMFS	68	(4)	50	(7)	72	(3)	60	(14)
Central part	101	(8)	96	(11)	101	(9)	99	(28)
Upper part	94	(6)	93	(2)	90	(4)	92	(12)
Average	91	(18)	80	(20)	93	(16)	87	(54)

14 of the 54 sites have score higher than 100 (see Hermansen 2008c Appendix 2).

The HMFS shows, as expected, much lower values (average score: 60) compared with average score 99 for the central part and 92 for the upper part. Average scores for the complete transects are quite similar for Mweka (91) and Marangu (93) and lower for Kilema (80). It is the low values from HMFS (50) along the Kilema transect which draws that average down. In the Kilema transect about double as many sites were measured in the HMFS part of the transect as in the two other transects. Sites on low altitudes are overexploited and well developed sites are situated on higher altitudes (Figure 5).

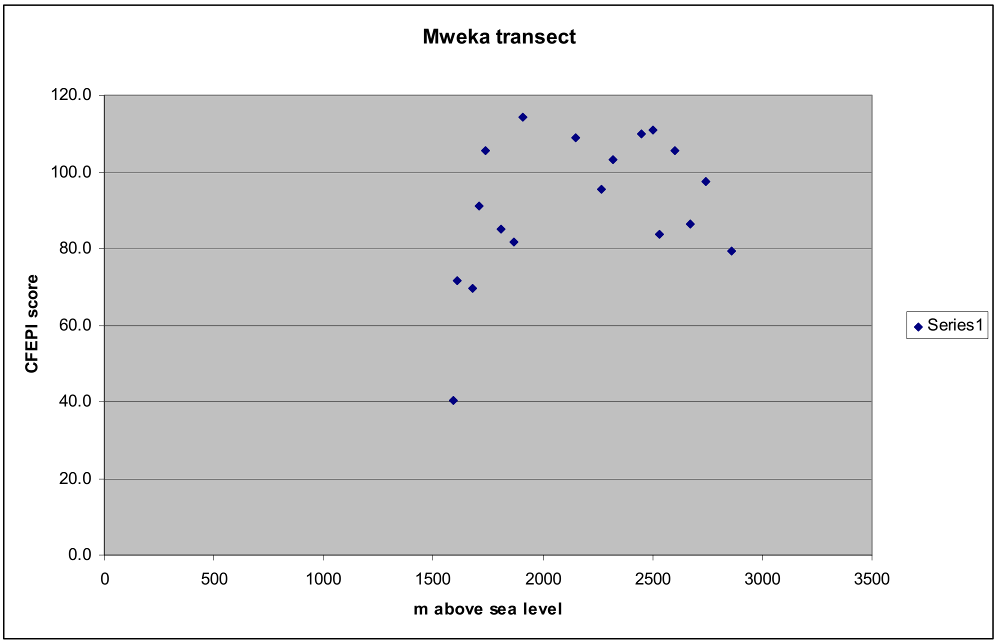

Figure 5 Proximity to target in percent for the sites along the altitudinal transect at Mweka. HMFS is between lower forest reserve border at 1590 and 1740 m asl and uppermost site at 2860 m (close to upper forest border).

7 Discussion

The objective of this thesis is to contribute to the inventory methodology for moist, montane and tropical catchment forests, and apply the methodology and results in constructing an ecological indicator that can serve as a mediator between the locals and globals.

The inventory methodology was carried out in as a collaboration between botanists and forest wards, and it seems to be a practical and useful way of analysing catchment forests. The results show that the different sites have, to a certain degree, a distinct character. The results from the inventory have value for forest management primarily as bases for mediation of forest quality in the sense of catchment forest and assessments of how far certain sites have been exposed of human impacts and especially severe encroachment.

The evolvement of proximity-to-target performance indicators shows that is possible to work out local ecological indicators which can serve as a measure for mediating and negotiating ecological values in a local versus global context. Due to the possible low threshold for understanding the ecological and ecosystem services information content, the indicator system should be a possible measure for increasing the symmetry between the locals and globals.

The scientific judgement of the feasibility of the inventory methods and FEMI indicator system will depend on expectations. The expectations in the present study include increased local participation, and then derivation of an indicator system based on practical ecological approach and a soft knowledge system. The measurement methods are partly vague and several variables are difficult to measure by exactly means. This fact can be regarded as positive in a mediation process, because the discussion of what to measure and how to handle data may stimulate the mediation.

8 Conclusion and further development

The study has evolved and demonstrated field methods for measuring ecological features essential for catchment forest management in montane, moist tropical forest where local people depend upon the ecosystem services.

The results from the measured variables are transformed to a proximity-to-target indicator, which are designed to be operational within a broad, multidisciplinary and multipurpose actor oriented management system between locals and globals where mediation of ecological knowledge is the paramount goal.

Further development of the field methods and the constructed mediation concept are required, and could include:

1. Testing of field methods on how representative they are for constructing an ecological indicator.
2. Transformation of the proposed mediation model to a practical model that could be tested out within the new forest management policy on Participatory Forest Management policy in Tanzania.

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APPENDIX 1

Acronyms and abbreviations

BEM	Balanced Ecosystem Mediation Framework
CBD	UN Convention on Biodiversity
CBFM	Community Based Forest Management
CFEMI	Catchment Forest Mediating Indicator
CFR	Catchment Forest Reserve
COP	Conference on the Parties to UN Convention on Biodiversity
CFP	Catchment Forest (Forestry) Project
DPSIR	Driving forces, Pressure, State, Impact and Response (Indicator system)
EEA	European Environmental Agency
EMI	Ecosystem Mediating Indicator
FAO	Food and Agriculture Organization of the United Nations
FBD	Forestry and Beekeeping Division (under MNRT)
FEMI	Forest Ecosystem Mediating Indicator
FR	Forest Reserve (NFR = National Forest Reserve
FSC	Forest Stewardship Council
HMFS	Half Mile Forestry Strip (Kilimanjaro)
IISD	International Institute for Sustainable Development
IRA	Institute for Resources Assessment (UDSM)
ISEAL	International Social and Environmental Accreditation Labelling
ISO	International Organization for Standardization
ITTO	International Tropical Timber Organization
IUCN	The World Conservation Union /International Union for Conservation of Nature
JFM	Joint Forest Management
LUCID	Land Use Change, Impacts and Dynamics
MA	Millennium Ecosystem Assessment (Coordinated by UNEP)
MDG	Millennium Development Goals
MESS	Mediation of Ecological Semantics and Sustainability (Model)
MNRT	Ministry of Natural Resources and Tourism (Tanzania)
NGO	Non-Governmental Organization
NORAD	Norwegian Agency for International Development
NRC	National Research Council (USA)
NTNU	Norwegian University of Science and Technology
PCI	Principles, Criteria and Indicators (Van Bueren and Blom 1966)
PFM	Participatory Forest Management
SAI	Social Accountability International
SKCFP	South Kilimanjaro Catchement Forestry Project
UDSM	University of Dar es Salaam
UNCED	UN Conference on Environment and Development (Rio-Conference)
UNDP	United Nation Development Programme
UNEP	United Nations Environment Programme
URT	United Republic of Tanzania
WB	World Bank
WBCSD	World Business Council for Sustainable Development
WCED	World Commission on Environment and Development (Brundtland Commission)
WCFSD	World Commission on Forests and Sustainable Development
WCMC	World Conservation Monitoring Centre (UNEP)
WRI	World Resources Institute

Glossary

Term	Definition
Appurtenance	A right, privilege or interest belonging to and passing with a principal stakeholder (or property)
Communication	The overall instrumental, technical and practical process of either mutual or one way directed interchange of physical and social relevant data, information or knowledge between parties
Constructs	"are specific types of concepts that exits at higher levels of abstraction and are invented for some special theoretical purpose. Generally, constructs are not directly tied to observations" (Davies 1996:26)
COP	Conference of the Parties
Data	Observed, registered or collected pieces of information
Epistemological	Used here as the scientific way of acquiring knowledge
Global	Here referring to globalized systems like science, UN-system, NGOs, international trade and culture, multinational business, industry and transportation etc
Globals	People, stakeholders and institutions relatively free from local resources, obligations and the duties to the daily life of community, and members of the globalized regimes of concern, politics, NGOs, business and science, with an acquiring of knowledge based on science (epistemological approach)
Indicator	The term indicator is used throughout this paper as a generic term for a key number of selected data or a constructed index which is used to illustrate a complex ecological phenomena or management area.
Information	Knowledge communicated or received concerning a particular fact or circumstances
Locals	People (and stakeholders) depending and bound to local ecosystem resources and control over resources, and with an understanding of their resources based on traditional experience and knowledge (ontological approach)
Knowledge	An organized body of information belonging to a certain context either acquired by experience or scientific work
m asl	Meters above sea level
Mediation	Here a process of kind, friendly and benevolent exchange of information and knowledge in order to better understand each other and agree upon a joint and collective consensus based on a fair and deliberate cooperation
Negotiation	Here a process based on arguments connected to specific position which the parties a priori want to protect, strengthen or support as much as possible through the process, while the parties are still interested in an agreement which they believe is better than no agreement.
Ontological	Used here as framework for acquiring knowledge about the life world based on experience from daily life and historical traditions
Universal	Here referring to concepts, knowledge and values that are shared by any culture, community or society.

APPENDIX 2

Paper I

From colonial to stakeholder rule (regime) – Perspectives on the forest management at slopes of Mt. Kilimanjaro, Tanzania

From colonial to stakeholder rule (regime) – Perspectives on the forest management at the slopes of Mt. Kilimanjaro

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Abstract

The purpose of the paper is to describe how forest policy and management in Tanzania have changed from pre-colonial time to the present. The paper observes four distinct periods; Pre-colonial, German and British colonial time from 1880s to independence in 1961, the Governmental centralised forest administration towards 1990s and thereafter a period with stronger emphasis on participatory and community based forest management.

The increasing emphasis on stakeholder approaches is discussed in relationship to initiatives like Millennium Ecosystem Assessment and the framework of ecosystem services is addressed.

The paper presents historical and present facts about the administration and management of the forest at the southern slopes of Mt. Kilimanjaro, including some thoughts and assumptions (generalizations) about the Chagga people and community relationship to the forested area and the forest administration.

1 Introduction

The purpose of this paper is to introduce a framework on how governance and administration of forest and forestry including policy and management has influenced the interests of local people regarding the use of ecosystem forest services at Mt. Kilimanjaro from the pre-colonial period to present situation.

The colonial period was characterized by strong impact of alien interests on forest resources and the local people's possibility for own control and influence on forest policy was limited. It is paradoxical that the recent years of globalization may have increased the global influence on local forest management, even though this time has also been characterized as neo-colonialism because of strong influence and dominance from the western market economy on the self-determination possibilities of the previous colonial countries especially in Africa,. The influence on local forest management today is, however, quite different and with other means than previously.

Today the conical and iconic mountain Kilimanjaro is encircled by a forested belt at the slopes between the upper forest line about 2700 – 3000 m a.s.l. limited by the harsher climate above, and the lower forest line at 1500 – 1700 m a.s.l limited by the forest reserve border against the cultivated areas inhabited by the Chagga people. Some areas are cultivated coffee estate or deforested areas from former logging and sawmill industry.

The forest belt has also been heavily exposed to encroachment and logging during the last 150 years (Hermansen 1985, Newmark 1991 and Lambrechts *et al*. 2002). Within the forest reserve and national park corridors, the forest policy for the last 30 years has been to restore the forest to a more natural and origin forest. Commercial logging is not allowed and there is a discussion on the future status of the forest.

For the local Chagga and Masai people and other tribes in the area, the forest at Mt. Kilimanjaro, must have been a veritable resource for hundreds of years in the pre-colonial time. After the occupation in the middle of 19th century, through the struggle for independence in 1961 and the period of building the new African nation, and thereafter the experience of globalization towards present, it must likely have been an experience where local influence has been a scarcity.

There are many strong interested and concerned parties that want to include the forest into Kilimanjaro National Park which at present encompass the mountain above the tree line (~2700 m) and four corridors through the forest (Newmark 1991). Originally the forest and Mt. Kilimanjaro were declared as a game reserve by the colonial government in 1910s and the area was gazetted as a forest reserve in 1921. The Mountain above the tree line was reclassified as national park in 1973[1] and opened to public access in 1977. The park was designated a World Heritage site in 1987.[2][3]

The status and quality of the tropical, montane, moist forest at the southern slopes of Mt. Kilimanjaro, Tanzania, is a result of many factors; implementation of forest and forestry

[1] Government Notice 50 1973
[2] IUCN (1987): World Heritage Nomination – Kilimanjaro National Park . IUCN Summery 403.
[3] UNEP/WCMC (13.05.2008): www.unep-wcmc.org/sites/wh/kilimanj.html

policy, the practical forest management by the central and regional authorities, and legal and illegal use by people from the local settlements and other interests that have harvested and exploited forest resources. International conservation and the tourist industry on mountain tracking have also played an important role.

The paper presents a brief historical overview of the forest administration and management from the colonial time to present in Tanzania, and aspects of traditional use of the forest resources by the Chagga people, and presentations of some management concepts including the catchment forest (forestry) concept, and the Catchment Forestry Project. The new stakeholder approach is especially addressed with a shift from a common forest approach.

2 From common forest to stakeholder forest

The forest ecosystem and forest resources at Mt. Kilimanjaro have been described by several authors and official institutions and authorities through the last decennials (See Bart *et al.* 2006 and Hermansen *et al*. 2008). In the context of this paper some aspects of ecosystem resources and threats to these resources will be presented in the context of the Millennium Ecosystem Assessment (MA 2005a,b,c), and its conceptual framework of ecosystem service.

The MA concept evolves from the traditional explanation of ecosystem to the more resource oriented ecosystem service term, which includes provisioning, regulating and cultural services that are supported by the basic ecosystem functioning principles. The services are further connected to features that constitute human well-being, and business opportunities (MA 2005c). An important feature of MA, which was not that important a feature in previous national forest conservation programmes, is the enlarged perspective that includes global concerns. The MA concept operates from local level via regional to global geographical scale and from short to long term time scale. The Millennium Ecosystem Assessment conceptual framework of integrations between forest ecosystem supporting functions and ecosystem services and corresponding constituents of well-being for human, requires a stakeholder approach in order to be operative.

Recently (Sjaastad *et al.* 2003) a resource economic analysis of the catchment forest reserves in Tanzania was commissioned and carried out by the Ministry of Natural Resources and Tourism (MNRT) through the Forestry and Beekeeping Division (FBD). Based on collected data and stakeholder theory, methodology and analysis, they explored the stakeholders and relevant resources for the Catchment Forest Reserves in Tanzania, including Kilimanjaro Forest Reserves. Among their many findings and recommendations they stated that that there are many stakeholders and stakeholder interests, ranging from the global climate control and conservation of biodiversity to the interests of local people and communities and livelihoods. The stakeholder concept will probably be the main perspective when the forest resources are to be managed in future (Grimble 1998, Grimble *et al*. 1995, Grimble *et al.* 1997). The Tanzania catchment forest reserve concept and the national forest management program Catchment Forestry Project, is a project that fit well into the MA concept.

World Business Council for Sustainable Development explores the business opportunities in the MA concept, often in collaboration with International Union for Conservation of Nature

(WBCSD-IUCN 2007), and they have suggested the schemes for Payment for Ecosystem Services (PES) which has being trialled in Viet Nam, and been found successful[4].
Zahabu *et al.* (2005) reports on PES as incentive opportunities for Catchment Forest Reserves management in Tanzania.

Examples on what MA (2005:21a) call promising examples on effective responses for the forestry sector, includes:

- *"Integration of agreed sustainable forest management practices in financial institutions, trade rules, global environment programs, and global security decision-making*
- *Empowerment of local communities in support of initiatives for sustainable use of forest products; these initiatives are collectively more significant than efforts led by governments or international processes but require their support and spread.*
- *Reform of forest governance and development of country-led, strategically focused national forest programs negotiated by stakeholders".*

A stakeholder model for forest management requires that it is possible for the different stakeholders to expose and advance their own interests in a form that is compatible with the principles and structure of the management system and stakeholder model that is applied. It is not enough to argue about rights and ecological constraints. It is necessary to argue about the value of ecosystem resources for different utilization. In this process the manner and form of how mediation of ecological values is essential, and often this kind of information will be conveyed using an indicator system as instrument.

A presumption for this study is that globalization has not increased the local people's "ownership" of the ecosystem resources and services from the forest at Mt. Kilimanjaro, but instead added local people together with other stakeholders on local, national and global level.

The stakeholder concept of forest resources could shift the management approach from single to multi purpose focus, from singular to multi purpose outcome from the forest resources, from individual to collective thinking about the benefit and larger concern about but the generation living today and future generation. Additionally, it is probably easier to valuate resources that will not be realized the next few years. Probably it will be easier to balance different interests, both on a practical level and a policy level. But there is also possibility that it will be easier for the interests representing the most valuable part of the resources to realise these interests without considering many of the others that are economically smaller and less powerful.

Another presumption for this study is that change in forest policy and management from pre-colonial to the globalized world has for local people like the Chagga people, altered from almost free access to forest resources (or managed through the traditional tribal governing system), through the loss of political control under the colonial time, through national planning and building of centralised administration under the first years of independence, to a stakeholder approach under the new globalized regime. Under the colonialism local people had to fight for control and rights over their traditional resources. Under the new globalized regime they have to argue for their rights and interests as stakeholders as also many other actors argue for their stakeholder interests.

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[4] WBCSD (04.09.2008) Paying for Ecosystems:
www.Wbcsd.org/plugins/DocSearch/details.asp?type=DocDet&ObjectId=MzEO

3 Forest administration in Tanzania

Regulation and management of forest in Tanzania goes back to the German colonial time. Local people like the Chagga people at the southern slopes at Mt. Kilimanjaro had governing systems connected to chiefdoms (Stahl 1964, Bart *et al.* 2006, Tagseth 2006, 2008), which partly continued into the colonial period.

The history of forest administration and management in Tanzania can be divided into the following periods:

- The original pre-colonial period towards the end of the 19th century.
- The colonial period from 1880s towards 1961. German colony from 1880s to 1919 and the British Mandate from 1919 to 1961
- Sovereign country from independence in 1961 (Tanganyika and Zanzibar from 1964)
- Globalization of environment with sustainable and participatory forest management from 1980s (WCSD 1987, WCFSD 1999).

These four periods can be divided and specified further according to general political and economic development and change on how forest policy has been administrated and managed. Change in status of rights and influence for local people is of course important.

3.2 Colonial period

The German Colonial Government provided the Imperial Ordinance in 1885 which shifted the ultimate control over land from native and traditional authorities to the colonial government (Lerise 2005:5). In 1918 the German lost Tanganyika to the British, and the ordinance was renamed to The Land Ordinance in 1923.

> *" The ordinance extinguished the superiority title of landowners, both individually and collectively. The ordinance also gave the government powers to resume possession of land granted under any rights or interest, should public purposes or interests so required, and to prescribe conditions under which rights granted by it could be*." (Lerise 2005: 183)

The main part of the forest that was gazetted as forest reserves then became under governance and management of the central authorities.

3.3 Independence

Before describing briefly the main policy documents on forest administration and management, it should be recalled that Tanzania after independence became famous for its attempts towards rural development and they nationalized and centralized the control of access to land, water, forest and natural resources. The government developed legislation, by-laws, guidelines, and plans for rural development in order to strengthen the conditions for people on fair and equal basis (Lerise 2005). The capitalist state under British colonial administration changed gradually to a socialist state; especially the 1967 Arusha Declaration and the Villagization Directive from 1968 and thereby founding of the Ujamaa state and villages was important in this respect.

Around 1980 Tanzanians faced economic as well as environmental crises (Lerise 2005: 3), and at the end of 1980s disputes in land rights, access to water and natural resources increased. Policy development regarding forest management changed due to the internal situation, the international process connected to the Rio summit and UNCED and many other new initiatives that were coming up on the international agenda.

3.4 National Forest Policies 1953 to present

The first National Forest Policy of Tanzania was launched in 1953 and reviewed in 1963 to manner which forest and tree resources should be managed in a sustainable way to meet the needs and desires of the society and the country.

In 1988 the Government of Tanzania initiated the preparation of the *Tanzania Forestry Action Plan* (TFAP). The plan was adopted by the Government in 1989, but the new plan did not lead to formation of new policies or revision of the sectoral legislation. During the period from 1992 to 1994 the plan was revised, with important contribution from the UNCED conference in Rio 1992, including the new global strategy connected to the forest principles, which continued by the Intergovernmental Panel on Forests (IPF). The new policy was prepared with involvement of relevant stakeholders, and the policy was based on analysis of the ecological and economic needs of the country and the availability of human and other resources.

The process of revising TFAP resulted in new comprehensive *National Forest Policy* (NFP) that was approved by the Government in 1998. In 2001 Ministry of Natural Resources and Tourism adopted the *National Forest Programme in Tanzania 2001-2010.* New forest legislation from 2002 expresses also a radical change where the previous focus on strong central control by the forest authorities is left, and to allow much more stakeholder oriented, community and private sector involvement in forestry.

The overall goal of the forest policy is to increase the contribution of the forest sector to the sustainable development of the country and the conservation and management of the forest resources to the advantage of present and future generations. (Ministry of Natural Resources and Tourism 1998, 2001, 2006, Sjaastad *et al* 2003).

3.5 Catchment Forestry Project and Catchment Forest Reserves

A catchment forest is in the widest sense every forest, since all forest affects the water balance of some watershed (Hermansen *et. al* 1985). In Tanzania it became associated with the denotation *Catchment Forest Reserves* and *Catchment Forestry* and related management projects. The German administration (1888 – 1920) was the first to include the principles of catchment forestry in Tanzania through gazetted forest reserves, and the British administration (1920-61) followed up the protection of these forests. After independence many forested areas were cultivated or deforested.

After the introduction of the Catchment Forestry Project (CFP) by the Forest Division of the Tanzanian Ministry of Lands, Natural Resources and Tourism in 1969 the governmental and central administration of the forests were strengthened on behalf of local management. But this governmental administered project CFP was not able to manage this forest well, and – together with international environmental initiatives which resulted from the UN process on sustainable development and the Rio-declaration on Sustainable Development, Declaration of Forest – the principle of people participation became stronger. By the turn of the millennium the local community had again become more responsible for the management of The half-mile forestry strip.

Forest structure, and forest management and utilisation are recognised to play a crucial role in watershed management, but forests also represent other kinds of values and forms of utilisation. Tanzania has developed a multi-purpose management concept operated by Catchment Forestry Project (CF-project) under Forestry and Beekeeping Division, Ministry of

Natural Resources and Tourism. The objectives of the CF-Project are to promote local community participation and maintaining and utilising the forest resources in a sustainable manner, and secure that the three key functions of the forest are maintained (Hermansen *et al*. 1985):

- generation, regulation and conservation of water resources and supply in the catchment area, and reduction of run off and soil erosion. It is especially important in moist mountain areas
- gene-pool conservation to prevent extinction of rare and endemic plant and animal species in the diverse moist forest. It is essential to maintain biodiversity and keep the genetic potential for ecological and evolutionary purposes and for present and future utilisation of biological forest resources
- production of timber from indigenous species and supply of forest products for local consumption and/or for sale.

Forested areas on mountain and hill slopes are considered to play a crucial role for water generation both in regard to water volumes, quality and spatially as well as seasonal distribution. A specific management is under development to include a multi-purpose management built on the recognition that the forest values can be determined both with biological, hydrological and forestry indicators.

3.6 Participatory Forest Management in Tanzania

The period from 1980 to 2005 can be divided in two phases. First, raising the necessary concern and approach for new multipurpose management strategies and second from 1995 on how effective management should be possible to implement, and implementing of Participatory Forest Management (PFM) and Joint Forest Management (JFM). PFM was introduced into law by the Forest Act of 2002 (MNRT 2006). The law provides for a legal basis for communities, groups and individuals on mainland Tanzania to own and manage (or co-manage) forest under a wide range of conditions under different kinds of PFM arrangements, e.g. enable local communities to declare and gazette village, group or private forest reserves. This is often referred to as *Community Based Forest Management* (CBFM)

Participatory Forest Management (PFM) has become the central strategy of Tanzania’s forest policy and the country has one of the most advanced community forestry jurisdictions in Africa (Blomley 2006). The awareness and achievement for more local involvement in forest reserves administrated by the Ministry of Natural Resources and Tourism under the Joint Forest Management (JFM) is also raised, and South Kilimanjaro Catchment Forestry Project (SKCFP) has entered into agreements with several local communities / villages on participatory forest management within the buffer zone of forest reserve (including HMFS and ravines and erosion sensitive areas beneath the forest reserve border) (Akitanda 2002).

4 Forest management at Kilimanjaro

4.1 The Chagga – people and relations to local forest resources

The Chagga people has for over 100 years been forced to deal with foreign governance and later, since the independence, of central national management of the forest resources at slopes of Mt. Kilimanjaro. The area was quite isolated from colonialists until the end of the 18th century, but under the German and later English colonial rule area cash crops (e.g. coffee) were introduced. This caused much of the forested land to become deforested and transformed to coffee plantations. The population increased and the density of shambas (family farms) increased. Logging and sawing of the valuable tropical hardwoods took place, and during the 1970s it became evident for the Tanzanian authorities that the forested area needed protection and that water management was critical.

The forest reserve which originally was gazetted for regulating and controlling the harvest of valuable hard woods, will in the case the southern slopes of Kilimanjaro, be changed to National park with a integrated management of some parts (the lower parts, HMFS, forested ravines etc) in cooperation with local authorities. For the Chagga people the question is probably to what degree will the central government and influence of the international society maintain control over their original forest resources?

On the inhabited agrarian land below the forest belt the population pressure and the pressure on land and ecosystem resources is very high. In addition comes the conflict and political problems with how and who should have control of and benefit from the water in rivers and furrows that are fed by the rainfall in the forest. Several studies on the stakeholder perspective, the understanding and the interests among the local Chagga people beneath the lower forest border on the southern slopes of Mt. Kilimanjaro have been carried out in recent years. The history of the Chagga people and their well developed family garden agricultural production system and societal system is covered by many authors (Stahl 1965, Akitanda 1994, Marike 2000, Tagseth 2000, 2006, 2008, Øyan 2000, Sjaastad *et al.* 2003 Bart *et al.* 2006).

The Chagga-people on the southern slopes of Mount Kilimanjaro has for at least 400 years (estimated by Marealle 1949) lived and developed a stable subsistence agriculture system based on a very good water supply by use of a rather advanced furrow-system that are leading water from the forest to their fields, manuring and erosion control (Kjekshus, 1997:34 and Rodgers 1993:285). The forest has also offered a generous source for wood, fuel, herbs and animals for many important needs (Sjaastad *et al*. 2003, Soini 2005)

The Chagga traditional and native administration systems was recognised as among the most advanced in Tanganyika, and was partly transferred to the Chagga Council (Stahl 1964, Kjekshus 1977, Lerise 2005, Bart *et al.* 2006).

Lerise (2005:186) refers to reports[5] on Chagga land tenure and the protection of river banks and steep slopes was introduced under the German rule, and later under the British Administration agricultural orders were issued by the native Authorities throughout the mountain and prohibiting cultivation near riverbanks, and the owners of the adjoining parcels were content to regard the riverbanks as communal grazing land.

Before 1941 the forest was managed by the central government, but in 1941 the HMFS was separated from the forest reserve and transferred to Chagga Council for local management.

Top-down land-use planning has lead to many problems in Tanzania, and is discussed by Lerise (2005:166) in his narrative study of Chekereni village at Lower Moshi. By referring to Oppen (1991)[6] and others he emphasises the need to change to a more participatory approach. He also refers to the National Land-Use Planning Commission which reported the following in 1996[7]:

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[5] Figgis, T.F. 1958. *A report on the present State of Chagga Land Tenure Practice*. Unpublished report for the Office of the Member for Lands and Mines. Page 19.

[6] Oppen, von A. 1991. *The importance of traditional rights of land use and rehabilition of degraded areas for the conservation of tropical forests – Case study of Tanzania.* Aide Memoir on short term consultancy study to GTZ. Tanzania.

[7] De Pauw, E. 1996. *Development of land use planning and land tenure in Tanzania. Main report.* Technical Support Services Project TSSI-URT/94/02T. April. Page 56.

"The main mistake made by the government is that it tried to impose land-use planning as a top-down solution without really having the capacity for good planning nor the means for enforcement. Land-use planning has always been seen in Tanzania as a "scientific" discipline and therefore the business of technical experts, with the land-users at the best in the role of information providers….The fact was ignored that in reality land-use planning is much or even more about suitability, and therefore more the business of the land-users themselves than of technical experts" (Lerise 2005: 166)

The forest at Mt. Kilimanjaro, however, has been under non-indigenous exploration and management since 1920, except for a belt of the lowest part of the forest, on the boarder to the agrarian landscape which is fed by water lead by furrows from the forested area above. This belt became in 1941 established as a forest under management of the Chagga Council and became denominated *The Half Mile Forestry Strip (HMFS)*, due to its extent of about 0.8 km depth into the forest (Newmark 1991, 2002).

Among the main challenges the society at the slopes at Mt. Kilimanjaro are facing today, is international attention and concern connected to conservation of ecosystem and quality as national park and top ranking tourist destination. Evidence for possible change of ecosystem during the next decennium due to climate change include increased temperature, changed hydrology with reduced precipitation and humidity which can increase the number of aggressive fires of the montane forest, furthermore resulting in change of the ecological factors determining forest structure and composition. (Hemp 2005, Agrawala et al. 2003)

4.2 South Kilimanjaro Catcment Forest Reserve (KCFR)

The South Kilimanjaro Catchment Forestry Project with headquarter in Moshi, is one of four CF-projects in Tanzania, and has been ongoing since the project was initially launched in 1976. Donor funding by NORAD started in 1988 based on agreement between NORAD and The Forestry and Beekeeping Division (Akitanda 2002a,b).

Management of the government owned protected forest reserves which where especially important for water conservation properties, was initially the main purpose of CFP. During several project evaluations, revisions of plans and funding agreements with donors the purpose more and more emphasis put on environmental sustainability, local participation and extension and training. Entering the new millennium the problem between the protection of forests, which was still a very difficult management task and encroachment like illegal cutting of timber, fuel wood collecting and grazing, still occurred many places on forest border and inside the forest around Mt. Kilimanjaro, and to manage to support the local people with adequate ecosystem services and corresponding constituents of well-being. New strategies and initiatives underline the following output (Akitanda 2002b: 3):

- Local communities involved of CFRs
- Improved human resources performance of CFRs
- Management plans developed and operationlized
- New initiatives for revenue generation developed and operationilzed
- Catchment forest resources economic analysis articulated

The collaboration with various sectors in the Kilimanjaro region and districts, cities and villages at the lower part of the slopes on Mount Kilimanjaro the Joint Forest Management (JFM) as involved some 63 villages in 2002 (Akitanda 2002b). The collaboration is verified by a signed agreement between the village authorities and KCFR, and involvement in forest management of local communities could include (from Akitanda 2002a,b):

The JFM shows that forest management change from being mono-oriented to multi-oriented and then how the stakeholder perspective emerge from the relatively national centralised previous governance system

An essential part of water management of Pangani river is appropriate use of land in the catchment area. Hills and mountain slopes are important areas for water generation to the rivers and to the ground water in the basin. These areas are often naturally covered with forest. The structure and physiognomy of forest and vegetation is important variables for hydrological models and basis for analysis of catchment areas.

4.3 Half Mile Forestry Strip

In 1941 The Half-Mile Forestry Strip (HMFS) on the southern and eastern slopes was established as a social and buffer forests under the Chagga Council to provide fuelwood and wood product for local people living close to the Kilimanjaro Forest, and Council successfully managed the HMFS for 20 years (Kivumbi and Newmark 1991 and Newmark 2002).

> *"An important reason for their initial success was that local people were able to benefit directly from its management. Local people were allowed to collects wood and wood products at minimal cost as compensation for their communal labour activities. An additional reason for the early success for the half-mile forestry strip was that forest regulations were fairly, yet firmly enforces." Newmark 2002:157.*

After has independence the management regime changed several times from being connected district authorities to South Kilimanjaro Catchment Project under the government. From 1941 to 2005 have the focus of the management changed from social forestry to more soil and water conservation and back again to encompass both aspects of social forestry and catchment forestry.

The summarily outline of the forest management history of HMFS is in this paper, is only meant as a context for understanding the trends.

Hermansen *et al. (*2008) showed in their study of structure and composition of the forest at the southern slope, that the forest in HMFS is still marked by severe encroachment. The encroachment was also documentated by an aerial survey by Lambrechts *et. al* 2002.

4.4 Kilimanjaro National Park (KINAPA) and future possibilities

There are many strong interested and concerned parties that want to include the forest into Kilimanjaro National Park which encompass the mountain above the tree line (~2700 m). Originally was the forest and Mt. Kilimanjaro declared as a game reserve by the colonial government in 1910s and the area was gazetted as a forest reserve in 1921. The Mountain above the tree line was reclassified as national park in 1973[8] and opened to public access in 1977. The park was designated a World Heritage site in 1987.[9][10]

If the catchment forest becomes included in the park, will probably the catchment and biodiversity aspects of the forest be protected, and the possibility for logging and timber production be reduced or even closed. HMFS may also be stronger protected, but it also probably that schemes like Payment for Ecosystem Services which has been tried in Viet

[8] Government Notice 50 1973
[9] IUCN (1987): World Heritage Nomination – Kilimanjaro National Park . IUCN Summery 403.
[10] UNEP/WCMC (13.05.2008): www.unep-wcmc.org/sites/wh/kilimanj.html

Nam with success, and is outline for catchment forests in Tanzania by Zahabu *et al.* 2005, will be suggested for the lower part of the forest belt including HMFS.

5 Conclusion

The paper presents epochs and events from the history of forest policy, governance and management in Tanzania and emphasises changes in forest policy from centralized governance and administration to participatory and community based forest management. International trends on stakeholder approach have also been introduced in Tanzania and are discussed in the paper. Decision making in the future may be more based on forest value for important stakeholder interest with reference to the principles of Millennium Ecosystems and the ecosystem service framework. Instruments and mechanisms for information about e.g. catchment forest values are then needed.

The catchment forest at Mt. Kilimanjaro and the Chagga people interests as stakeholders to the forest are discussed.

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APPENDIX 2

Paper II

Mediation of tropical forest ecological interests through empowerment to locals

Mediation of tropical forest ecological interests through empowerment to locals

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Abstract

Globalization and global concerns for tropical moist forest have impact on the vital necessities for local, indigenous people who are either living in or close to the forest and depending for their daily life on the quality of ecosystem resources the forest provides.
The paper explores how the tension between global and local interest, and differences in how the knowledge about the forest ecosystem is acquired, can be mediated and negotiated between interested parties. Catchment forest management at Mt. Kilimanjaro, Tanzania, is background reference case for this interpretation.

In the study are challenges connected to the different positions between the locals and globals discussed regarding forest ecosystem services and sustainability, and how ecological mediation between locals and globals can be understood based on actor network and stakeholder approach.

A framework on ecological methods where ecological semantics can be a mediator between nature (ecology) and culture (society) in order to evolve a common understanding for environmental sustainability and valuation of ecosystem service is suggested. From this framework another framework for mediating ecological indicators is evolved in order to keep the elements of local versus global interest, nature versus society and epistemology versus ontology together in one system.

Keywords: Ecological indicator, Ecological communication, intercultural mediation, ecological epistemology, ontology, tropical forest management, actor network

1 Introduction

Globalization and global concerns for tropical moist forest have impact on the vital necessities for local, indigenous people who are either living in the forest or close to forest ecosystem resources on which their daily life quality are depending. This paper explores how the tension between global and local interest, and differences in how the knowledge about the forest ecosystem is acquired, can be mediated and negotiated between interested parties. Catchment forest management at Mt. Kilimanjaro, Tanzania is used as tableau for the evolvement of the presented contructs.

Norton (1998) address the failures of ecological communication when it comes to ecological risk and ecological based management decisions due to the lack of terms, indicators and measures that are *"based in ecological science, but are also associated with important social values*" (1998: 350). He suggests that ecological communication should be integrated in a broader adaptive-management system in which both scientific hypothesis and social values are evaluated within a system of management which could include an integrated language of management that is adaptive, perspectival, multi-scaled, operationalizable, normative in content, and communication enhancing.

The important question is, however, within what kind of communication regime could the wanted ecological communication take place? The challenges raised by Norton relates to the efforts handled in this paper and a previously suggested model for ecological communication and the appurtenant mediating ecological indicators (Hermansen 2008b). With reference to tropical forest management three actor based management concepts are identified as possible framing for the ecological communication (Hermansen 2008a):

1. Governmental, more or less based on ideology, with centralized forest administration.
2. Privatized and stakeholder oriented management emphasizing economic yield.
3. Community-based and stakeholder oriented management with stronger local participation emphasizing ecosystem services to the local community

Alternative three is selected for further discussion in this paper, because it represents the most essential new approach for local people's access to forest resources in tropical countries like Tanzania, and has became the main approach adjusted to new UN initiatives and institutions for multipurpose forest management aiming to preserve forests both as functioning ecosystem and as sustainable resource for the benefit of local people and country (UNCED 1992, MA 2005a,b, UNEP 2007).

The classification above can be further enriched with other actor oriented perspectives in order to make the ecological management and decision making more suitable for being analyzed in depth by studying the meandering pattern of ecological communication (Hermansen 2006), in addition to the well-known stakeholder analysis which is a much applied tool for management and governance.

The Actor Network Theory (ANT) (Law and Hassard 1999) is in this paper used as theoretical resource for assisting a shift in perspective from social and economic cause versus effect discourse, to a more open discourse involving the interconnected relationship between human and non-human actors, and between science and nature (Latour 1988, 1993, 2004).

In the study the stakeholder perspective mainly represent human interests in the resources, while actor network perspective comprises an enhanced understanding of the role and impact both from human and non-human in the process of problem solving. Elkington (1998) also addresses the so called quasi stakeholders as nature and future generation as legitimated new stakeholders, but usually they are not a part of traditional stakeholder analysis (Grimble and Wellard 1997).

A framework on ecological methods and how ecological semantics can be a mediator between nature (ecology) and culture (society) in order to evolve a common understanding for environmental sustainability and valuation of ecosystem services is proposed. From this framework another framework for mediating ecological indicators is evolved in order to keep the elements of local versus global interest, nature versus society and epistemology versus ontology together in one system.

2 Mediation of ecological semantics and sustainability

Ecological communication embraces internal ecological scientific discourse and mediation of different ecological positions, as well as the discourse and mediation of ecological topics between nature and culture. Due to the crucial role of ecosystem services for sustainability and the inwrought of ecology with society, will also ecological communication be a part of intercultural communication. Intercultural communication is not only communication between different societies and traditional collectives of people. In this paper intercultural communication is a denotation of interests, positions and strengths for stating and forwarding ecological arguments between different collectives on global and local level.

Norton (1998) is asking for an integrated language of management that is adaptive, perspectival, multi-scaled, operationalizable, normative in content, and communication enhancing. In short, he is addressing how ecological information and knowledge can be mediated and negotiated within a system where better and ecological acceptable environmental management decisions can be made. In the following chapters is an ecological mediation concept is presented that may also provide the integrated language asked for by Norton.

Ecological indicators in general, which is the mediated object in a mediation system, can here be regarded as a "*Machiavellian*" instrument (Latour 1988, Hermansen 2006) because it is a construct that is designed and constructed by ecology (or ecologist), and the purpose of this construction is gathering control and influence over the ecological field of interests. In the presented model for mediation and appurtenant indicator locals are invited into the process of designing, constructing and the employment of the ecological indicator. Locals may then become "*Machiavellian*" partners together with the globals.

Globals (Bauman 1998, Bird and Steven 2003, Strassberg 2003, Hermansen 2008b) denotes people, stakeholders, actors and institutions relatively free from local resources, obligations and duties of the daily life to a community, and members of the globalized regimes of concern, politics, business, science etc. Locals are stakeholders and actors dependent of and bound to local ecosystems resources. An assumption in the suggested model is that globals and locals are stakeholders and actors that often seemingly will not have concurrent interests, but during a genuine mediation and negotiation stronger concurrent interests will appear, basically due to acceptance of traditional rights and the common acknowledgement of the threats to forest ecosystem.

Requirements to a fair, democratic and enlightening oriented model for ecological communication includes as a minimum that the model is open, suited for deliberation between interest groups and gives the opportunity for stakeholders and actors to reflect on how ecological knowledge is gained and controlled.

Figure 1 illustrates the Mediation of Ecological Semantics and Sustainability (MESS) for discursive handling of management challenges between ecology and society. Different ecological approaches are distinguished and made suitable for communication between participants in the discourse, where there exists great differences in background conditions and asymmetry regarding the possibility to obtain necessary power in resource conflicts and global public discourse.

MESS is developed from another model of the relationship and interaction between ecology and sustainable production and consumption, where industrial ecology was suggested to serve as hub for mediation and negotiation (Hermansen 2006: 90).

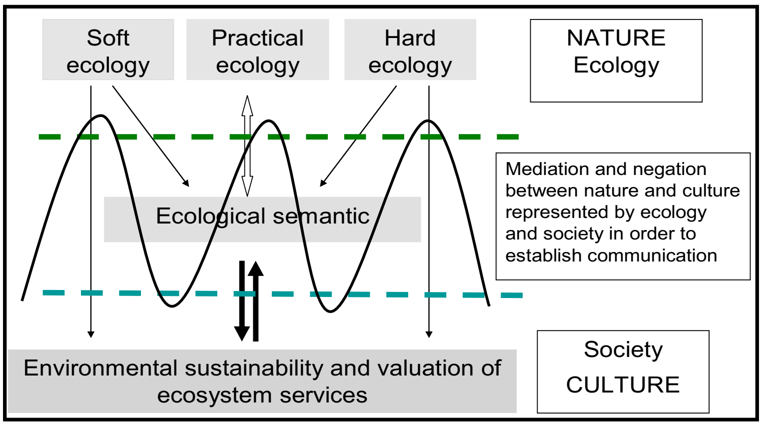


Figure 1 Model for Mediation of Ecological Semantics and Sustainability (MESS).

The model shows the semantic and rhetoric functions of ecological communication as hub for mediation and negotiation between nature represented by an ecological approach and culture represented as a society.

Essential features of the model are the diversification of ecology into soft, practical and hard ecology (Shrader-Frechette and McCoy 1993, Shrader-Frechette 1995) interpreted for this kind of mediation models by Hermansen (2006), and the mediation and meandering processes between culture and nature (Latour 1988) also interpreted by Hermansen (2006).

Practical ecology represents here the daily and regular communication of an intrinsic and ontological character. Hard ecology is representing communication which is strongly epistemological defined scientific ecology. Soft ecology is representing a strong and traditional understanding or belief of how the ecosystem services are part of a holistic and mythological understanding of environment. Soft ecology is the tacit base for an ontological approach for local people and is often the ultimate position for explaining the cause and mechanism behind the appearance of practical ecology. The explanation of practical ecology can be moved towards soft or hard ecology. It is possible to achieve a deeper understanding of both soft and hard ecological knowledge through practical ecology.

Local people that mainly have been involved in ecosystem services and ecosystem description by using practical and soft ecological approach should be more involved in the new understanding of ecosystem services and management provided from the hard ecology.

Globals, especially scientists, could probably learn more, and then make their contribution to ecological theory more relevant for the practical ecological realities which the locals experience daily.

The model represents a structure that can help different stakeholders to understand the difficulties of ecological communication between different epistemological approaches and ecological practises. Translocation of knowledge involves loss of information and accuracy and depends on the interface or membrane between the sub-elements in the communication system. One way arrows in Figure 1 represent communication passing an interface like a semi-permeable membrane where the useful information goes in one direction, while the two way arrows represent mutual permeable interfaces. The bold arrows indicate that the results of the mediation are applied within ecosystem management.

In the image of mediation, with transfer and translation of information between the scientific ecology system and experienced social practise system, can genuine compromised ecosystem management occur.

The central block is the hub for hypothesising on the relations between the ecological sphere and efforts for looking for negotiated sustainable ecosystem management solutions

Between the actors there must be some common units of information that is possible for all parties to understand and put relevant meaning into from their own positions. Ecological indicators designed for this purpose are appointed to be bearers of the messages. The purpose of ecological indicators in this context is to function as a mediating and negotiating agent between the nature represented by ecology and culture represented by society (including the local community and international ecologically and environmentally concerned society of scientist, politicians, NGOs and citizens in general), and thereby as a kind of consensus indicators in the category of practical ecology. These are the most fair and effective indicators to ensure a proper protection of ecosystem with a frame of the local community and proper and sufficient scientific quality of the indicators.

So far the explanation and interpretation of the MESS are dealing with human's interests, understanding and participation, but the model is also meant to show how non-humans take part as actors and contribute to the mediation. Nature (e.g. a moist, tropical forest) will, when studied in an ecological scientific context, contribute directly to the negotiation due to the change in reflection on ecology that will occur on the scientific side, and by direct experience to local people living by the forest by the direct impacts on their life the ecosystem service will have. This will moderate, sometime change, their understanding of the forest as nature.

MESS cannot be used directly as an operationalizable model for concrete mediation of ecological information in form of e.g. ecological indicators. Another model has been designed for this purpose. The model is called the Balanced Ecosystem Mediating (BEM) Framework (Hermansen 2008b) will be presented in section 6.

3 Actors and mediation of ecology

The introduction of actors in MESS is in the study done on two levels. Within environmental management the stakeholder perspective is well-known. The actor network perspective enlarges the actor perspective to include non-humans and meandering process between almost every kind of interest that may contribute to construct of a system where relations is essential.

3.1 The stakeholder perspective

Ecosystem resources are many places under heavy pressure from human activities. Interests and conflicts over environmental resources are today often understood and discussed in terms of stakeholder analysis (Grimble and Wellard 1997, Grimble 1998), and in Tanzania Sjaastad *et al* (2003) have made a stakeholder analysis of the catchment forest reserves for the Tanzanian government. In addition to the traditional stakeholders new groups of quasi stakeholders are also important when mediation of ecology is discussed (Elkington 1998).

Ecological indicators cannot exist in a vacuum without any differences in interests, preference and privileges involved. Conflicts, and other relationships between privileged and underprivileged regarding natural resources interests have to be dealt with. Ecological indicators, as many other kinds of socio-economic indicators, have their great advantage in that they can to a certain degree (depending on the character of the social power structure) be considered and applied as relatively neutral and objective mediators of information necessary for understanding the situation and finding solutions. A stakeholder analysis with the overall aim of promoting sustainable development must support dialogue and discourse for problem solving processes, and relevant ecological indicators are mediators of necessary information. A stakeholder analysis where the intention is to favour some interests which often is the case may be problematic, especially when they are not supporting the fair interests of local people.

Elkington (1998:166) stresses the importance of stakeholders in driving the sustainability transition, and that *"any stakeholders analysis needs to distinguish between 'traditional' and 'emerging stakeholders'* ". Traditional stakeholders usually comprise shareholders, lenders, regulators, governments and politicians, and the emerging stakeholders include employees, customers, consumers, trade organizations and coalitions, professional and academic organisations, community and environmental groups. Elkington also introduce a category of 'surrogate stakeholders' among emerging stakeholders which includes vague interests such as the planet's biosphere, the world population, and future generations.

A stakeholder analysis can be regarded as a vague and politically acceptable measure to clarify different interests compared to e.g. socio-economic class analysis or natural resources allocation (Grimble 1998, Grimble and Wellard 1997). A dialogue oriented process is probably easier to establish in order to solve conflict of interest. Due to the broad purpose of this paper, we have suggested an additional typology for stakeholder analysis that includes the influence, control and understanding of ecology and ecological terminology, indicators and mediation of forest values and qualities.

Joe Walker (2001:61-62) has suggested that the "design questions regarding assessments of ecological conditions can be reduced to (1) who wants this information, (2) how reliable is the measure, (3) what should the output look like, and (4) how does it link with management. This could also be an interesting starting point for discussion of ecological indicators for tropical forest, and it is by now means certain that globals and locals will have the same answers.

3.2 The actor network perspective

Asking the question "*why ecology*?". What is purpose of the science of ecology? The answer may be that we sometimes do ecological science for gaining new knowledge about ecology. Other times we do ecological research to get in a better position for solving problems relating to protection of ecosystem and ecosystem service. Locals are probably best served by wise management and protection of local resources and ecosystem service.

The complexity of cultural and political reciprocity or asymmetry of ecological communication is here denoted as intercultural mediation of the process by assigning ecological values through indicators.

A follow-up question could be: Is it possible to unify the global and local understanding and evolve a common indicator concept? Or is the local destined to lose their understanding of forest, as their own resources due to their outdated mental and cultural understanding of forest value cannot be included in the globals scientific understanding? To open a theoretical framework for handling the complexity between the global and local perspective, between nature and society and the formation of a communication basis between the stakeholders or actors involved, are resources based on Bruno Latour, Michel Callon and John Low and others theory on Actor Network Theory (ANT) applied (Latour 1987, 1988, 1993, 2004 and Law and Hassard 1999).

The new initiatives of more local participation and collaboration between locals and globals (professionals) require a new kind of interchange of forest ecological information that may be met by a forest ecosystem mediating indicator (see Hermansen 2008b).

The difference between our assumption of the global and local position is that global is associated with the nature pole of the nature-society dichotomy and local is associated with the society pole. We do that assumption based on the anticipation of the importance of and close relationship between ecological science and institution and bodies involved in convincing people about their great concern for environment by using scientific based arguments, while the local people are just depending on resources that the forest provides.

This paper tries to recreate a balance between locals and globals by making local actors more visible and stronger by enlarging the scale so both locals and globals can be seen simultaneously by using elements and resource from ANT and theory on mediation between nature and culture (Latour 1988), and on quasi objects (Latour 1993).

The ANT can briefly be defined as heterogeneous network of aligned interests, and ANT explores how human and non-human actors form networks where some kind of construction or problem solving may occur. Mediation contributes to the interchange between the social and scientific parts and how they can be seen together and controlled by an actor which can take lead position for evolving solutions for new problems or challengers that are appearing. The quasi object or quasi product is the denotation of an object that cannot only be a scientific part of the network (even if it is only handled among scientists – here plant ecologist – and accepted as scientific). The reason is that within ANT the elements are connected together in ways where it is difficult to allocate phenomena as either belonging to the nature pole or on the society pole. The ecological indicator designated for being the piece of information between the sub-elements of a forest management system is neither a piece of ecological scientific information or social information. It is something between – a quasi object.

The process of evolving the principles for a new construct on which a new kind of forest indicator should rest on, could be interpreted as interchange between local knowledge and control over ecosystem services on one side and the global concern and scientification which are trying to capture the understanding of the local forest on the other side.

An ecological indicator based on plant ecological measurement will usually be characterized to be a scientific product or object due to the scientific work behind the object.

4 Ontological versus epistemological approach to communication and management of ecology

Basically we can learn about ecological realities either through daily life experience and interaction with the natural environmental (ontological approach), or through research and education by using a scientific methodology (epistemological approach). For science studies Latour (1999: 15) claims that there is no sense in taking independently of epistemology, ontology, psychology and politics because nature and society (and God and mind) cannot be cut off from each other. It does, however, depend on how political the term *ecology* is used. Latour (2004: 131) wonders how the most anthropogenic word in ancient Greek ("oikos" means human household) has become the word for understanding the nature without humans. Ecology and ecological are also in this paper sometimes used more or less as the origin and native denotation for nature just as when local people refer to nature in an ontological context. It is possible and necessary to keep the term allocated to mainly to denote scientific ecology and purposes. As many specific professional terms in other fields like electricity, virus and philosophy, will ecology also be used on different definition level.

The term and field of scientific ecology has, since it was coined by Ernst Haeckel in 1861, been an object for discussion within different natural sciences and is in many respect well defined therein, regard to theory and research methods. However, since ecological phenomena are crucial to all kind of human social activity and self consciousness, the term is also inwrought in our daily perception of the environmental mind set. For that reason "ecology" has also gained interdisciplinary attention, and its potential for ethical and political implications has become a subject for debate in the social and management sciences as well. Shrader-Frechette and McCoy (1993) and Shrader-Frechette (1995) give important input to the diversification of ecology from soft to practical and finally hard ecology. This diversification can be used as a frame for detailed discussion along a scientific – non-scientific gradient.

Due to the heavy impact ecological resources and concern has on society, ecology often appears as a political term. Bruno Latour (1991, 2004) is one of the authors who challenge the conceptual context of the terms ecology and political ecology.

When evolving ecological indicators in the framework of this study, at least three perspectives of the use of ecology may be addressed:

1) How is the science of ecology understood and mediated?
2) Is ecology synonymous with nature?
3) What is political ecology?

A discourse on assessment and management of natural biological resources like forest involves today the term ecology, especially in global and intercultural contexts.

One possible intervention that can be used for understanding the political role of ecological understanding as a premise for ecological management and communication is to apply and modify Bruno Latour's allegory on Machiavelli's "*Prince*" (Latour 1988). An important aspects of this model is that power has to be understood as a consequence of the kind of relations between those interests that are capable to understand how the society and nature can be mediation and negotiation between the two sides convey construction of something that is scientific possible and societal acceptable. Hermansen (2006) has modified Latour's model to describe technology as a construction between nature and culture on an ontological or phenomenological level and between ecology and society on an epistemological level. This modification should still be considered as an allegory based on Machiavelli's "*Prince"*. In our case we are questioning how local people can influence "*what is societal acceptable*" regarding management of forest resources.

The model of the nature/culture meandering process gives us the opportunity to consider and analyse on a very general level how people, independent of their culture, can understand their relationship and dependence on the natural environment. An understanding of the ontological approach based on Antony Giddens' concept for ontological security (defined as "*confidence or trust that natural and social worlds are as they appear to be, including the basic existential parameters of self and social identity*" (Giddens 1984/1999: 375)) is also useful for the discussion of how ecology is understood by locals. It can be compared with ontological security which describes how children possess a fundamental security relationship to their parents which constitutes their trust in their surroundings and contributes to the formation of a child's self-identity. After years of growth, the child learns that uncertainty, problems and mistrust must be solved by processes that require skills and proficiency depending on experience, theory and methods which are earned by the individual's own development, education etc. Very often these are collected from and built upon the common pool of human knowledge and experience (Giddens 1990: 79ff).

Similarly, humans' "*trust in nature*" and nature's capacity to provide them with food, shelter etc represents a kind of ontological relationship. Nature gives to humans from its surplus, but also takes, often brutally, human lives and necessities for survival. The society thereby experiences insecurity and threats. In this case it relates to environmental threats and challenges that require the mobilization of skills and knowledge to maintain security. In the Millennium Ecosystem Assessment framework is security, support of basic material needs and health as a constituents for human well-being directly linked with ecosystem services including the mediation by socioeconomic factors (MA 2005a,b).

The ecology-society meandering process gives the opportunity to consciously reflect over this relationship by studying problems related to our physical environment based on empirical science and social science and think about solutions. The "*Prince*"-model depicts also a process-oriented and realistic understanding of the role of manager of forests regarding new sustainable forestry methods, as well as for engineers and technologists regarding development of technology. The forest managers can play the role of mediator and negotiator between the two sides of nature and culture by using theory, methods and pragmatic problem solving from natural science and social science. As mediator the manager and other professionals can be the interpreters between the dimension of science and society and as negotiator she will be an active agent to find solutions between what is scientifically possible and socially or culturally wanted or acceptable. The construction can be depicted as a meandering between the nature side and the culture side. The actor carrying out the meandering or construction could be any professional within handling possible interest from stakeholders to forest ecosystem services. This role also includes re-negotiation where the engineers see quite another solution when the original or traditional forestry of forest management procedure has failed, been outdated, or are not serving the interest of important stakeholders. The consciousness among forest managers about this role is, of course, also important for the self-understanding and the knowledge in the profession regarding their practical work.

5 Ecology and ecological indicator

Ecological indicators are parts of constructed communication systems for mediation of ecological and environmental information and knowledge between actors, stakeholders or affected parts. Basically an ecological indicator is a part of the paradigm of ecology and biology, but when an ecological indicator is meant to mediate information from ecology to biology it is rather a cross-disciplinary exercise and may also include cross-cultural phenomena that go beyond ecology and involve economy, politics and philosophy. A communication system is often not neutral to the parties involved and it is plausible to assume that a de facto distinction or discrimination exists between science and management oriented intruders and the traditional experience and understanding of the forest by the native people in area. From literature on the rationale of ecological indicators the impression is that the purpose often is the development of indicators as a practical tool for monitoring and assessing environmental status, identifying trends and supporting decision making for environmental issues that create public concern about environmental conditions (Kurtz *et al*. 2001: 49-60).

5.1 Public ecology

The communication system can basically be specified as three categories of stakeholder communication dependent on status and interests of people and communities involved:

1. Between experts within the same field of profession (same paradigm)
2. From expert within one field to representatives form another field or to qualified persons and institutions
3. From experts to lay people or not scientifically qualified people and institutions.

Category 3 can be divided into two subcategories: 3a) the content and consequences of using the information that is mediated are of minor importance and 3b) the consequences are of major importance for peoples´ welfare and control over there own resource base. For all categories certain assumptions, open or tacit premises and intrinsic norms and values will be a minor or major part of the foundation of the communication system.

The journal Ecological Indicators presented the result from a work shop on ecological indicators and indications where the focal point of interest was the linkage between theory and practice in environmental indication (Müller and Lenz 2006: 1-5). The contributions mainly deal with the representation of ecological knowledge in general the state of ecosystems, and how indicators can be capable of representing the ecosystem features and not only single variables. Using indicators with emergent properties could meet this challenge (2006: 4).

Robertson and Hull (2001: 970-979) advocate a more public ecology to address the challenge of making conservation biology more effective in the political arena of decision making. This paper explores the possibilities to construct ecological indicators that reduce the distance between those who, often from remote position geographically and dependency of the forest, are defining that the forest and forest values, and the local people who are directly depend of the forest resources. To approach a platform for common understanding of the two parties, we discuss the concept of ecology along two perspectives. The first perspective is how ecological knowledge can be learned and understood from an ontological and epistemological angle. The second perspective is dealing with how ecology concepts be developed can be used.

Of course ecological indicators can deliberately represent a scientific model of understanding forest (that means then the ecosystem forest or particular forest) and serve a scientifically based environmental management system and ecosystem services oriented approach to optimized utilization of forest resources.

5.2 Indicator

Despite universal anthropological faculties, the gap between local and global information gathering, interpretation and use becomes obvious, for example in the case of ecological indicators for a sustainable forest management. Scientific contributions describing or outlining the context, concept and criteria for selecting ecological indicators are mainly concerned with the scientific quality of indicators and the modern environmental monitoring and management system that the indicators are meant to serve.

Indicators, in this setting, could be referred to as ecological, biological or environmental. The purpose of constructing indicators is to help us understand and communicate certain aspects of our environment in an neutral and objective way usually from skilled people (experts) within a discipline of professions to other unskilled (non-experts) in the discipline, but they may very often be experts in other disciplines.

Especially in a society (local or global community) under heavy pressure or rapid change the need for monitoring, assessing, evaluating and decision making on behalf of the natural environment is crucial.

According to a great number of ecological aspects and properties are extracted and analysed from the entirety that makes up the totality of the environment. But it is very difficult to mediate this diversity of parameters (measurable factors which help to define a particular system) from one expert group to another, from experts to laymen, or to people with another culture and tradition without any connection to a scientific approach to nature. Ecological indicators are of course part of a larger system. They can be considered as pieces of information that are able to reflect the status of a system (Hunsaker and Carpenter 1990) and pass the interface between the different elements of the larger system. The system in the context of this paper consists both of global and local actors and interests, and of globalized life world and the *cosmopolitan* life world (Nederveen Pieterse 2006). Schiller *et al*. (2001) discuss the relationship between Common-Language Indicators and individual ecological indicators for forest. The context is how complexity of ecological issues are communicated to parties or stakeholders to fully engage in a dialogue on value aspects of the environment.

Some very few environmental indicators such as weather forecasts (temperature, precipitation) have been internalized in the society for many years. They have been a part of daily concern especially for farmers, sailors etc, but they have a very directly and immediate impact on daily life activities. Very different from weather indicators is climate indicators where the direct observation and experience is weak and uncertain. Laymen have to rely on experts that are using complicated models, analysis and interpreting trends and changes many years ahead. It is difficult to understand why emission of some gases to the atmosphere should cause an increase in average global temperature in the future. Another aspect more relevant for this paper is indicators describing the condition of an ecosystem such as mountain rain forest. How could any useful information from a complex system as a rainforest ever be communicated by some few digits to different kind of stakeholders? Müller (2005) is discussing the dilemma between a holistic, interdisciplinary, management oriented approach on one side and number of ecosystem variables necessary for giving a sufficient representation of the ecosystem.

The word ecology, with two different meanings, belongs to the two different life worlds. Ecology is the science about the living part of nature, but ecology is also often used as the notion of the living part of nature, and as a synonym to nature and even environment. Giving ecology this notion, we then do not need to use the word nature (Hermansen 2006).

Ecological integrity (Westra and Lemons 1995) is often regarded as a prerequisite for a representative indicator system for a certain ecosystem (Angermeier and Karr 1994, Dale and Beyeler 2001, Andreasen *et al*. 2001). To communicate the scientific concepts of ecological indicators to non-scientists can according to Dale and Beyeler (2001: 8) be done by teams including social scientists, but "*integrating ecological indicators with social and economic goals for resources management remains a big challenge*". The reason is obvious because local authorities, farmers and foresters living in a certain area are often concerned with a pragmatic interpretation and utilization of the resources and the question about indicators and their scientific interest in results and further development is low.

Addressing this gap the discussion should move to how social and human factors and interests could be included in an ecological indicator system, and how the indicators could evolve to some kind of locally integrated and understandable ecology indicator or environmental sustainability indicator. Few authors address the mismatch between a traditional understanding and interpretation of ecological resources for local, native people and the apparatus and machinery of scientific understanding of ecology and modern (often top down) environmental management regimes on international, national and local level.

How to evaluate indicators are crucial (Kurtz *et. al* 2001) but will not be covered in this paper

6 The Balanced Ecosystem Mediation (BEM) Framework

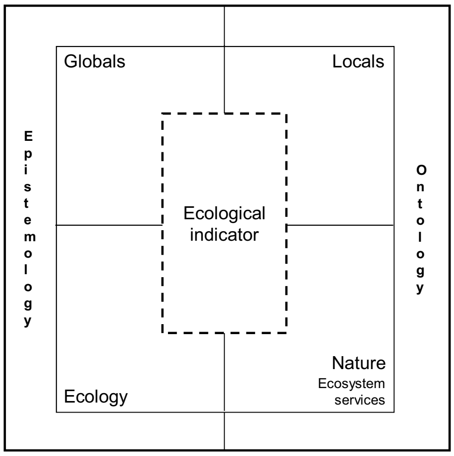
The construction of an ecological indicator is built on a pre-understanding of communication as an instrument for mediation and negotiation of knowledge and interests, and that these processes are integrated and accepted as fundamental for further use within a certain environmental management structure. Technically, most environmental indicator systems are designed within an open system concept which includes conceptual, normative and operational elements. The notion about system often encompasses "*a combination of interacting elements organised to achieve one or more stated purposes*" (Haskins 2006), and could be an assemblage of elements constituting a natural system, a man-made system, an organizational system or a conceptual knowledge system (Asbjørnsen 1992).

An ecological indicator system aiming to be a management tool can be defined within all these four classes of systems and also merged into an overall communication system where the indicator and the different circumstances around the indicator become elements in the system. The challenge is to design and understand how the interaction across the boundary interfaces between the elements, the subsystem and eventually the environment outside the system boundary, influence and bring the system into being. System thinking is an underlying concept used to assist in combining the ecological and social elements in the development of an indicator system which moves form ecological approach closer to a management and stakeholder approach.

The vertical line S and horizontal line V and their crossing point illustrated in Figure 2, represent the ideal symmetric or balanced case based on scientific and normative criteria and arguments. How to define the crossing point and symmetric and balanced state is a matter of mediation and negotiation. The impact from human utilization of forest resources can not have impacts on the forest ecosystem function that ecologists can not accept. The vertical lines a, b and c illustrate different constellations where the position, influence and control by the locals is more or less reduced or lost to the globals. The line a shows the situation where the locals are incapacitated and have lost almost all control over their ecosystem resources, line b represents the situation where the locals have managed to participate in forest management, and line c the situation where the locals have substantial influence and control over local ecosystem services.

If V is moving upwards the ecological concerns increase with stronger emphasis on protection and conservation, and if V is moving downwards the society takes more of the ecosystem services with an increased ecological unsustainability and even a strong attenuation of the ecological resilience capacity.

The BEM framework should be regarded as an open system where the borders between the elements and subsystem are interfaces where mediation and negotiation can occur between the stakeholders involved. Both mediation and negotiation can take many forms depending on the question discussed or the stakeholders (and subgroup of stakeholders) participating in the discourse.



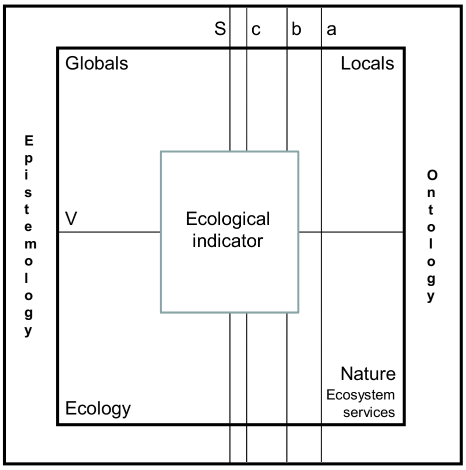


Figure 2. The construct of the Balanced Ecosystem Mediation (BEM) Framework with the two knowledge regimes ontological and epistemological. S and V are representing the ideal typological symmetry (or balance) regarding mediation and negotiation for globals versus locals stakeholders and actors and society versus nature (as quasi stakeholder or non-humans actor) respectively. The indicator is here meant to be an Ecosystem Mediating Indicator (EMI).

7 Conclusion

The paper discusses the asymmetry between foreign stakeholders and actors (the globals) and local affected people (the locals) when it comes to defining and controlling the system of ecological understanding of the quality of tropical forest ecosystem by means of ecological indicators.

Based on the assumption that there is a universal will for balancing and even out some of the asymmetry and give more influence back to locals, two models for mediating forest resource qualities are suggested:

- The general model Mediation of Ecological Semantics and Sustainability (MESS)
- The specific Balanced Ecosystem Mediation (BEM) Framework.

Based on BEM an operationalization can be expressed in an ecological and intercultural integrated language, which can enhance ecological communication. A scientific acceptable system that is understandable and fair for locals, can be designed and employed in forest ecosystem management.

9 References

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APPENDIX 2

Paper III

Industrial ecology as mediator and negotiator between ecology and industrial sustainability (Hermansen 2006)

Industrial ecology as mediator and negotiator between ecology and industrial sustainability

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Abstract: This article discusses hybrid theory development efforts within industrial ecology. The framework is Latour's (1988) Prince metaphor, which he expanded to describe machines and machinations, technology and society. Technology including industrial ecology is regarded here as mediator between nature and society. Aspects on standard ecology and principles for ecosystem thinking as background for our knowledge of natural environment are discussed, in particular the novel understanding of transformation in human and natural systems by means of panarchy and adaptive cycles. Adaptive cycles are also considered as mediation between nature and society. However, natural, scientific or biological ecology are difficult to use directly as a platform for environmental management. A diversification of ecology into soft, practical and hard ecology facilitates the understanding of the relationship between scientific ecology and industrial ecology. Combining both in a model may emerge illustrating the construction of industrial ecology and sustainable production and consumption society and showing the dynamics between nature and society.

Keywords: industrial ecology; ecological communication; industrial sustainability; ecology; mediation between ecology and industrial ecology; ecology and management; construction of industrial ecology; adaptive cycles; hybrid research.

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APPENDIX 2

Paper IV

Structural characteristics of the montane, moist forest on the southern slopes of Mt. Kilimanjaro, Tanzania

Structural characteristics of the montane forest on the southern slope of Mt. Kilimanjaro, Tanzania

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Abstract

The forest reserve on the slopes of Mt. Kilimanjaro, Tanzania, is an important catchment area and the major water source for several hundred thousand people in the Pangani River Basin, and can be categorized in three types of states. First, forest compartments previously under logging and forestry management, second, undisturbed forest especially in ravines and difficult accessible areas, and third, the so called “Half-mile forestry strip” that constitute a buffer zone to the agricultural area below the forest reserve border. The forest management is organised within ‘The Catchment Forestry Project', and the objective of the management encompasses protection of three categories of ecosystem services: water conservation, timber and other forest products, and biodiversity.

The procedure and process of analysing the quality, status and trends of the structure and diversity of the tree composition of forests is fundamental for providing relevant information and knowledge for proper management and decision making regarding the forest ecosystem services. Mediation and communication of ecological information between the global and professional level, and the local and indigenous level is a dimension of tropical forest management that is crucial for a successful management practise. The study intend to contribute to the development of a field work methodology including presentation of results that is deliberative and applicable for meeting the requirements both from a plant ecological scientific position, and from the increasing demand for greater influence and participation from local communities and stakeholders regarding the management and protection of ecosystem resources.

Totally 54 sites with the size 1000 m^2 have been analysed along three altitudinal gradients regarding structural properties and tree species composition.

Keywords: Mt. Kilimanjaro, Tanzania, catchment forest, forest inventory, forest structure, physiognomy, moist montane tropical forest, ecosystem service, ecological communication.

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Botany, both at University of Dar es Salaam, Ministry of Natural Resources and Tourism, Forestry and Beekeeping Division, and Kilimanjaro National Park.

1 Introduction

1.1 Issue

The procedure and process of analysing the quality, status and trends of the structure and biodiversity of the tree composition of montane, moist, tropical forests is fundamental for providing relevant information and knowledge for management and sustainable use of the forests ecosystem services. The study seeks to contribute to the development of a methodology including presentation of results that is deliberative and applicable for meeting the requirements both from a plant ecological scientific position, and from the increasing demand for greater influence and participation from local communities and stakeholders regarding the management and protection of ecosystem resources. The study includes detailed registration and analysis of a number of variables of all trees from 54 sites along three orographic gradients relevant for assessment of the main ecosystem services which the forest can provide.

1.2 Context: Forest and management at southern slopes at Mt. Kilimanjaro

The field work is performed in the forest belt at the southern slopes at Mt. Kilimanjaro, Tanzania, between the lower forest border at about 1700 m a.s.l where the forest buffer zone called *Half-mile forestry strip* (HMFS*)*, meets the agricultural landscape of the Chagga peoples family farms, and the upper forest border where the forest meets the harsher climate at about 3000 m a.s.l. The forest serves both as major water harvester for the whole Pangani river basin, and provide ecosystem services for several hundred thousand people, and feeding the furrows of the traditional irrigation systems to the farms at the mountain slopes (Stahl 1964, Misana 1991, 2006, Newmark 1991, Øyan 2000, Tagseth 2000, 2006, 2008, Ngana 2001, 2002, Misana *et al.* 2003, Røhr 2003, Røhr and Killingtveit 2003, Bart *et al.* 2006). The structure and physiognomy of the forest has large impact on the water balance and forms important variables for hydrological models and other investigations and analyses of the catchment forests.

Historically the management of the forest started under the German colonial time in the 1880s. The forest has been exploited by logging with several sawmills operating inside the forest until 1970s when logging was suspended due to overexploitation. In 1941 the HMFS was separated from the forest reserve and transferred to Chagga Council for local management (Newmark 1991, 2002, Kivumbi and Newmark 1991).

Catchment Forestry Project (CFP) under Forestry and Beekeeping Division of the Tanzanian Ministry of Natural Resources and Tourism (MNRT) was launched in 1977. It resulted in a weakening of the local management and a strengthening of governmental administration and forest management of Kilimjaro. CFP did not manage to handle the forest well, and encroachment, deforestation and fragmentation of the catchment forests increased (Hermansen 1985, Newmark 1992, Akitanda 1994, 2002, Mariki 2000, Sjaastad *et al.* 2003, Lambrechts *et al.* 2003). The objectives of the CFP are to promote utilising the forest resources in a sustainable manner, and secure that the three key functions of the forest are maintained (Hermansen *et al*. 1985):

> ***Water generation****, regulation and conservation of water resources and supply in the catchment area, and reduction of run off and soil erosion. It is especially important in moist mountain areas.*
>
> ***Gene-pool conservation*** *to prevent extinction of rare and endemic plant and animal species in the diverse moist forest. It is essential to maintain biodiversity and keep the genetic potential for ecological and evolutionary purposes and for present and future utilisation of biological forest resources.*
>
> ***Production*** *of timber from indigenous species and supply of forest products for local consumption and/or for sale.*

During the last 20 year has the forest policy strengthen the aspects of sustainability and local participation both internationally (WCFSD 1999, MA 2005, FAO 2005) and in Tanzania (MNRT (1998, 2001) inter alia the *Participatory Forest Management* (MNRT 2006) which where introduced by law in 2002, and *Joint Forest Management* which takes place on reserved land and forest reserves (Akitanda 2002).

The stakeholder perspective has emerged to be an important part of the management approach. Sjaastad *et al.* (2003) make in their resource economic analysis on behalf of MNRT a stakeholder analysis of catchment forests and shows also the need for solving serious challengers connected to encroachment and insufficient management. Interests in and conflicts over environmental resources are today often understood and discussed in the perspective of a stakeholder (Grimble 1998). The recent years has the stakeholder concept strengthen its importance as the conceptual frame work for natural resource management (MNRT 1998, 2001, Sjaastad *et al*. 2003), and one of the purposes of the investigation presented here, is that ecological indicators could emerge, that can mediate the ecological information to and between the different stakeholders (Mendoza and Martins 2006). Such methods should be based on general management principles which include strategies for development of indicators for a multi-scaled nature conservation approach (Lindenmayer *et al.* 2006). Indeed the traditional ecological knowledge should also be given its rightful place in the analysis (Sallenave 1994). Stakeholders comprise local community of affected people with traditional beneficial rights, but also the global community of ecological science, management and environmental concern. Mendoza and Martins (2006: 19) concludes that:

> "*Stakeholders or decision makers must be able to participate and contribute actively to modelling – from identification of model elements, formulation of relationships, and all other model components, including the actual decision-making process. This call for a more transparent, simple, and accessible participatory modelling paradigm and process.*"

Forestry studies and assessment of forest resources have to a large extend been mono disciplinary in their approach depending on the defined and usually relatively limited purpose of the study. Well known are industrial forest inventories that are mainly assessing the forests in terms of commercial timber production. An ecological approach to forest studies on the other hand tries to consider the forest not only as a resource for the forest industry, but its total value, also for organisms not directly of economic value. One important objective of plant ecological studies of forests is to mediate scientific acquired ecological information and knowledge about the ecological quality of the forest to stakeholders. Robertson and Hull (2001: 971) discuss and argue for "the term *public ecology* to draw attention to the public decision making context to which conservation knowledge is applied". Many forest ecosystems and forested areas are under special concern due to their importance for local and regional ecosystem services and as constituents of well-being.

1.3 Forest inventories at Mt. Kilimanjaro

Forest field studies in the forest at Mt. Kilimanjaro can be group into three categories based on purpose of study: forestry, ecology, and integrated and management.

Industrial forest inventories like the Jakko Pöyry (1978) inventory is focusing on volume estimations and quality of the commercially valuable timber trees, e.g. *Ocotea usambarensis*, *Macaranga kilimandscharica*, *Xymalos monospora* and *Podocarpus latifolius*.

The second category represents registration of plant species and vegetation analysis, often along orographic gradients. Many of the earlier works were floristic and qualitative aiming to document biodiversity. Later also the vegetation was studied, but still with the main emphasis on the trees and shrub and identifying the different horizontal vegetation belts (Pike-Jones 1948, Hedberg 1951, 1955, Salt 1954, 1955, Greenway 1965, Pike 1965, Sampson 1965, Wood 1965a, b).

The period from 1980 to 2005 can be divided in two phases where the ecological concern and management have been emphasised. The first is about the work for raising the necessary concern and approach for a new multipurpose management strategy, and the second from 1995 is about how an effective management should be possible to implement. During the 1980's it became clear that a more powerful action was necessary in order to implement the forest management strategy for the forests at hill and mountain slopes, and during the 1990s also works on biodiversity increased. Hermansen *et al.* (1985), Bjørndalen (1991, 1992), Newmark (1991, 2002), Katigula (1992), Lovett and Pocs (1992), Lovett and Wasser (1993), Howell (1994), Malimbwi *et al.* (2001), Ngana (2001, 2002) describe and discuss ecological and catchment aspect and forest management of the forest of Mount Kilimanjaro. Kashenge (1995) prepared on behalf of MNRT the management plan for 1995-2000.

From 2000 and onwards several works have been published which also encompass and integrate aspects of catchment forest management. Malimbwi *et al.* (2001) developed and made an inventory under the new system of collaborative forest management which include reliable information on forest standing stock for rational decisions in management and also allows for the interests of the local community. Hermansen *et al.* (2002) presents preliminary results from inventories of the structure of forest sites. Yanda and Shishira (2001) analyse changes in the forested area and resource utilization and William (2003) is reporting a case study on the implications of land use change on forests and biodiversity from the HMFS at Mt. Kilimanjaro. Lambrechts *et al.* (2002) presents an aerial survey of the threats to Mt. Kilimanjaro forests. Malimbwi *et al.* (2001) launches inventory and monitoring methodology which are aiming to meet the need for information under the new system of collaborative forest management, rational decisions in management of forest resources. William (2003) has examined the land use changes in Mweka and Lyasomboro villages in Moshi Rural District and how these changes have affected resource use, forest cover and biodiversity in HMFS based on aerial photos from 1952 and 1982.

Hemp has published several articles from Mt Kilimanjaro including works about *Erica excelsa* (Hemp and Beck 2001), ecology of pteridophytes (Hemp 2001, 2002), climate change (Hemp 2005) and contributed to an OECD report about climate change (Agrawala *et al.* 2003). Hemp (2002, 2006a) and Agrawala *et al.* (2003) have also systemized the vegetation in vegetation zones along the altitudinal gradients including biodiversity, encroachment, forest and heath fires and possible climate change. Hemp (2006b) also discusses long-lasting influence and disturbance of both human and large animals on the patterns of diversity, endemism and vegetation belts. He suggests that the low rate of endemism of the lower altitude forest compared to the Eastern Arc Mountains may be a result from destruction of forest rather than the relatively young age of the Kilimanjaro.

Huang *et al.* (2003) carried out a study in the forest reserve of the neighbouring area of East Usambara Mts, Tanzania of the effects of tropical forest structure and composition of species diversity by using data from 279 plots. They found that species diversity was significantly influenced by structure and composition of forests as it account for a great number of habitats. Madoffe *et al.* (2005, 2006) presents a baseline of selected forest reserves from a forest health monitoring project in the Eastern Arc Mountains of Kenya and Tanzania. The methodology, which includes 43 permanent plots, is developed in order to present three main indicators of forest health: mensuration, visual crown ratings and tree damage.

A large multi-purpose project mainly using remote sensing techniques has recently been published (Bart *et al*. 2006) and Schrumpf *et al.* (2007) on soil and catchment.

2 Study area

Mt. Kilimanjaro is a volcanic complex with two high (Kibo and Mawensi) and one lower (Shira Plateau) summits, and with a basal diameter of some 80 km raising from the plain at 700 m a.s.l to the highest summit at 5896 m. It is located 300 km south of the equator between 2°45′ and 3°25′ S and 37°00′ and 37°43′ E.

The slopes are in many places incised by ridges and deep valleys with rivers in the bottom which also form important location and ecological basis for an increased and different biological diversity (Hemp 2001, 2006b). The most important ecological abiotic factors are topography, soil and climate. Impacts from previous logging and utilisation are in some sites very distinct. There are few sites which are undisturbed and contain large, old trees. In several sites there are sign after large stumps from previous logging probably *Ocotea usambarensis*.

The study area comprise 54 sites of 1000 m^2 along 3 transects passing through the Forest Reserve (Catchment Forest Reserve) on the southern slope of Mt. Kilimanjaro. The map (Fig. 1) shows the location of the mountain, indication of moist, montane forest belt surrounding the volcano, and three transects named Mweka (T1), Kilema (T2) and Marangu (T3) after the nearest village (and park gate) from the lower forest reserve border and to the upper forest border.

2.1 Soil

The soil in the forested belt is treated in Newmark (1991), Griffith (1993), Ngana (2001, 2002), Hemp (2001), Pomel (2006) and Bart and Pomel (2006). Soil condition related to change in vegetation, rain forest succession and rainfall is especially covered by Schrumpf *et al.* (2006, 2007). The aim of the 2006 study was to investigate the organic C, N, S and P nutrients in rainfall, throughfall, litter percolate and soil solution of the forest and the influence of disturbed forest and thus very relevant for catchment forestry. Important findings where that for all vegetation types increased the concentration from rainfall to throughfall and litter percolation but then rapid decreased in the mineral soil. This is probably caused by the high sorption capacity of the soil formation andisols at Mt. Kilimanjaro.

Important findings in the context of catchment forestry from Schrumpf *et al.* (2007) where among other factors that the study "*showed different aspects of the nutrient cycle on disturbed sites of Mt. Kilimanjaro are not only affected immediately after disturbance, but altered for decades by impeded regeneration on clearings*" (2007: 253). They found that the opening of the forest (with shrub and secondary forest) at lower altitudes led to higher variability of nutrient concentration in seepage water and an increase in concentration of dissolved nutrients in the upper soil layers. It may be due to higher litter turnover rates because of higher nutrient concentrations in the litter and warmer temperatures on the clearings (Schrumpf *et al.* 2007: 253)

2.2 Climate

Few measurements over a long period and along the total altitudinal gradient have been performed on Mt. Kilimanjaro and therefore it is not possible to give an overview over the climate of the whole Kilimanjaro system (Røhr and Killingtveit 2003, Blot 2006), but during the last years more measurements have been performed and published (Hemp 2006a). However, the variation in temperature, precipitation and humidity along the altitudinal gradient from the dry plain upwards the agrarian slopes, the forested belt between 1600 and 3000 m a.s.l. and further through the heath and dry alpine zones to the glacier at summit, is very large. This variation determines together with man's influence and the historical development the great variation of the vegetation.

In the context of water management the hydrology of the area is covered by Ngana (2001, 2002), Røhr and Killingtveit (2003), Røhr (2003). Hemp (2001, 2002, 2005, 2006a) discusses the climate in relationship with the vegetation differentiation at the southern slopes of Mt. Kilimanjaro.

There are two rain seasons, the main from March and including May and another one, usually with lesser amount in October to December (Bart and Pomel 2006). There is a gradient in annual rainfall with altitude. The annual rainfall is less than 500 mm on the plain (Blot 2006, Bart and Pomel 2006). In Moshi at about 800 m a.s.l. the annual precipitation is 850 – 862 mm (Blot 2006, Bart and Pomel 2006), but 14 km northwards at 1479 m a.s.l. the amount is 2229 mm (Bart and Pomel 2006). The highest annual precipitation is measured at 2200 – 2300 m a.s.l. (Røhr and Killingtveit 2003). However, Hemp (2001: 494, 2006a: 30) indicates from his own measurements a maximum of about 3000 mm at 2100 m a.s.l. Above the forest the precipitation is much lower, at 4600 m a.s.l. only about 300 mm according to Blot (2006).

Both the annual amount and the annual distribution vary from west to east. At an altitude varied between 1250 and 1450 m a.s.l. the annual rainfall is 430 mm on the west slope (Friesan Farm) on the southwest slope 1108 mm, on the south slope in Lyamungo 1525 mm and in Rombo on the east slope 1720 mm (Bart and Pomell 2006). On the south slope about 60-65 % of the annual precipitation falls during the main rain season between March and May, but in the east part at Rombo only about 43 %. Also on the west slope at Friesan Farm the differences in the rainfall amount between the main rain season and the season October – December is less pronounced (Bart and Pomel 2006, Fig. 30).

The establishment of the large reservoir Nyumba ya Mungu may have changed the local climate, at least on the plain. The precipitation at a station 9 km away from the reservoir increased with 39% (Røhr and Killingtveit 2003).

The annual mean temperature in Moshi (813 m a.s.l.) is about 23.4°C, at 3100 m 9.2°C, at 4000 m 5.0°C (Hemp, unpublished data in Agrawala *et al.* 2003, Hemp 2006a) and at the top of Kibo -7.1°C (Thompson *et al*. 2002).

At Lyamungo the precipitation has decreased since 1935 with about 11% which equals 177 mm (Agrawala *et al.* 2003). From Amboseli region, north of Kilimanjaro, a 25 years record shows an increased temperature with a rate of 0.275°C per annum (Agrawala *et al.* 2003). The famous glacier at the top of Mt Kilimanjaro is melting. Data suggest that with the increasing temperature the glacier "will have disappeared by the year 2020" (Agrawala *et al.* 2003). The contribution to the run-off from the glacier is probably minimal.

2.3 Vegetation

Hemp (2002), slightly changed in Hemp (2006a), has suggested an altitudinal zonation of the vegetation (Table 1) on Mt. Kilimanjaro based on his study of the orographic distribution of first only pteridophytes and later a more complete vegetation comparison between the belts on other mountains in the tropics including the variation based on bryophytes launched by Pocs (1994). With reference to Frahm and Gradstein (1991) Hemp points out that bryophytes and pteridophytes are excellent tools for analysing altitudinal zonation of tropical mountains due to their good properties as indicator of climate factors, and that they have much wider ranges than most vascular plants and that they are fewer in species than those.

Hemp's altitudinal division (2002, 2006a) included plantations below the forest, forest remnants in gorges and along riverines, forest within the Half-mile forestry strip and the shrubland above the forest (Table 1). His two divisions (2002, 2006a) differ to some degree and here is a short description of his last division (Hemp 2006a, b). Below 1800 m a.s.l. forests exist mainly in gorges and along riverines. However, in these parts the biodiversity is highest and culminates between 1000 and 1300 m a.s.l. (Hemp 2006c). His first forest belt is called *Ocotea – Agauria* or *Ocotea – Syzygium* with the species *O. usambarensis*, *A. salicifolia*, *S. guineese*, *Macaranga kilimandscharica* and *Polyscias fulva* as important trees. Above about 2200 m a.s.l. a forest composed of *Ocotea usambarensis*, the conifer *Podocarpus latifolius* and the tree fern *Cyathea manniana* develop. In the next belt *Podocarpus* dominate over *Ocotea*. Higher up, at about 2800 m a.s.l. the contribution of *Hagenia abyssinica* changes the forest to a *Hagenia – Podocarpus* with *Prunus africana* or to a forest dominated completely by *Erica excelsa*. The dominance of *E. excelsa* is a consequence of fire (Hemp and Beck 2001, Hemp 2005).

2.4 Half-mile forestry strip and human interference

Encroachment is occurring to a great extent and affecting the forest in the forest reserve (cfr. Lambrechts *et al.* 2002). Especially in Kilema area the activity was high. People are daily gathering fodder, fuel wood and saw logs even above the HMFS. Encroachment in Kifura along Mweka transect seems to be more under control. Clear cut areas have been replanted with local tree species. Some stands are not maintained and weeds and shrubs conquest the land and prevent the tree to grow up. Many planted trees are also destroyed and broken. Field and shrub layers are relatively dense. Along the HMFS part of Kilema transect, which follows the ridge between Mzhiri and Ona rivers, is the tree layer more open than in the Mweka transect. The HMFS part of the Marangu transect is also rather open with areas occasionally grazed by cattle between the trees, Forest structure in the sites is relatively heterogeneous due to large difference of human impacts. In some sites along Kilema transect stumps from newly cut trees where observed.

3 Materials and Methods

The structure of the vegetation was investigated and analyzed in subjectively selected sites along three orographic gradients from the lower forest border (Forest reserve border) to upper forest border (Table 2). It included the Half-mile forestry strip (HMFS), situated between the lower forest border and about 1.5 km into the forest. The forest is partly heavily disturbed, especially in this strip. The three transects were from west to each called Mweka, Kilema and Marangu (Table 1, 2). Field work was performed in the period 1998 and 2004. The sites were selected on the criteria that they should be representative of the vegetation of the different altitudes and forest utilization. Totally 2384 trees/stems distributed over 49 different tree species were measured in the 54 sites.

Transect 1 – Mweka transect started at the forest reserve border at Kifura plant nursery and the National Park Ward at Mweka Gate, and comprised 18 sites from 1590 to 2860 m a.s.l. along the Mweka route. The first four sites were situated in the Half-mile forestry strip (Table 2, Appendix 1).

Transect 2 – Kilema transect started at the forest border at a ridge between Ona and Mzira river in Kilema North Ward (Rua village) and followed the track, and comprised 20 sites from 1780 to 2670 m a.s.l. The first 14 sites are situated about 100 m from each other. From site 15 the sites were along the track/road passing the old saw mill. The seven first sites were placed within HMFS (Table 2, Appendix 1).

Transect 3 – Marangu transect started a few hundred meters inside the Marangu National Park Gate and followed the eastern track/road named rescue road, and comprised 16 sites from 1820 to 2620 m a.s.l. and the first 3 sites were within HMFS (Table 2, Appendix 1).

3.1 Field measurements

Each site was 50 m x 20 m (1000 m^2) in size and was laid out with measuring tapes. In places with steep terrain and dense tree and shrub cover a path were cut in order to lay out the sites correctly. The sites were marked in the field by red painting on the trees positioned closest to the corners.

The position of each site was measured by GPS and the altitude with a Thommen barometric altimeter. As the information about altitudes were uncertain, we measured altitudes several times at the same points calibrating the altimeter every morning and evening at the same point in Moshi town (see

Appendix 1, 2). Further, the slope of the terrain and the exposition were measured. The exposition and slope is given in gon (^{g}) (new-degrees), 400^g (gons) equals 360° (degrees).

Within each site all individual trees were identified to species, numbered, and measured, except in the sites no 13 and 14 in the Marangu transect. These sites were very dense and in these, only stems in a representative subarea were measured. However, all stems were counted. Totally 54 sites comprising 2384 stems (some trees were divided at basis and grown into two, three or four stems) were measured. Species identifications were sometimes a problem, and in these cases leaf and twig materials were collected for comparison with herbarium specimens. Another problem has been a varying nomenclature.

All woody individuals (except climbers/vines) with a diameter at breast height (1.3 m above ground level) of 10 cm and larger were included. For trees with several distinct stems, each stem was measured and registered. A minor study of field and shrub layers was performed in each site, but is not treated here, as the trees contribute most to the catchment properties.

At the stand level, besides the physical site variables, total cover as crown projections separately for tree (canopy), shrub and field layers, were estimated in percentage of the site area. At the individual tree level, tree height (m, estimated, but a few individuals were measured with a Suunto height meter), diameter at breast height (DBH) (m) (for big trees in stead the circumference), height to lowest branch (m, estimated), crown diameter (m, estimated in two dimension, the longest diameter and the longest in right angel to that, with stepping on the ground), trunk shape (straight=0, leaning=1, bent=2, crooked=3), buttress (yes=1, no=0), cover of climbers and vines, cover of vascular epiphytes and cover of epiphytes of bryophytes and lichens on the tree stem, were measured/estimated. The cover of climbers/vines and epiphytes was estimated individually for each tree stem with a 6 degree scale, 0: almost nothing observed, 1: $x < 10$ % cover of the tree stem, 2: $10 \leq x < 25$ %, 3: $25 \leq x < 50$ %, 4: $50 \leq x < 75$ %, and 5: ≥ 75% coverage.

3.2 Calculations and statistical analysis

3.2.1 Calculations

Species richness, as number of tree species, was summarised per site. Based on the stem diameter measurements, the total basal area of the site was calculated. The crown projection for each tree individually, and the sum of the individual crown projections was calculated for each site. This last variable differs (being higher) from the estimation of the crown cover projection estimated in the field, as individual crowns covered over each other. Further, mean site values for a number of the measured variables were calculated.

3.2.2 Statistics

Spearman' rank correlation test was run to test correlations between the stand variables. In addition linear and quadratic regression tests were run for all stand variables with altitude as the independent variable. These tests were both run with all sites included and with only the sites above the Half-mile forestry strip included. The tests were employed using SPSS, S-plus (2005) and SigmaPlot (2006).

4 Results

The forest especially in the Half-mile forestry strip between the lower forest reserve border and about 1.5 km into the forest (Table 1, 2), which has been under local management, was heavily disturbed, especially the sites along the Kilema transect. Along the Mweka transect the first 4 sites, along the Kilema transect the first 7 and finally along the Marangu transect the first 3 sites were placed in the Half-mile forestry strip (Table 2).

4.1 Physical characteristics

4.1.1 Elevation

The Mweka transect encompassed an altitudinal difference of 1270 m, starting at 1590 and ending at 2860 m a.s.l. and with an average altitudinal difference between the investigated 18 sites of 71 m (Table 2, Appendix 1). The average altitudinal differences between sites in the two other transects, Kilema and Marangu were 45 and 50 m, respectively. Both these transects were also shorter in altitudinal differences between the lower and the upper border (Table 2, Appendix 1). They both started higher up and ended lower than the Mweka transect.

4.1.2 Exposition and slope

Nearly all sites were exposed more or less towards south, between 140^g (gons) and 200^g. A few sites (11) in transects 1 and 3 were exposed towards west, between 230^g and 300^g (Table 2). The slope of the sites varied between 2^g and 40^g, with some differences between the three transects, with an average slope of about 10^g (Table 2).

4.2 Tree diversity and flora

4.2.1 The flora

Forty-nine species were found in the tree layers in the 54 sites (Table 3). Species number per site amounted to between 2 and 14 with an average of 6.5 (Table 4, Fig. 2a). Thus, the diversity was in general rather low. Most of the species have a geographical distribution pattern described as occurring in eastern, southern Africa (Lovett *et al.* 2006) (Table 3). A few in addition occur also in central Africa (Table 3) (Lovett *et al.* 2006). One species, *Pittosporum goetzei,* should according to Lovett *et al.* (2006) occur only in the Eastern Arc forests, but was found in site 14 in transect 1 (Table 3). *Psychotria cyathicalyx* occurs besides in the Eastern Arc also in northern Tanzania, but nowhere else (Lovett *et al.* 2006).

The following species have a more widespread distribution in Africa than that of the majority, *Podocarpus latifolius*, *Tabernaemontanum pachysiphon*, *Polyscias fulva*, *Cordia africana*, *Erica excelsa*, *Albizia gummifera*, *Xymalos monospora*, *Olea europaea*, *Pittosporum viridiflorum*, *Allophylos africanus* (Lovett *et al.* 2006). The following species occur in addition also on Madagascar, *Ilex mitis*, *Schefflera myriantha*, *Aphloia theiformis*, *Albizia gummifera*, *Maesa lanceolata*, *Myrsine melanophloeos*, *Pittosporum viridiflorum*, *Prunus africana* (Lovett *et al.* 2006). One species, *Clausena anisata*, occurs also on Comoros Island (Lovett *et al.* 2006). *Erica excelsa* occurs so far to the north as in the Mediterranean region, *Maesa lanceolata* on the Arabian peninsula, *Pittosporum viridiflorum* to southern India, and *Olea europaea* with different taxa so far as in Iran, India and China (Lovett *et al.* 2006).

4.2.2 The altitudinal distribution

No species were found in all sites along the whole altitudinal gradient (Fig. 3). Nine species were found in 10 sites or more, *Xymalos monospora* in 40 sites and *Schefflera goetzenii* in 32 sites. A few species were found in many sites with a large altitudinal variation, such as *Ocotea usambarensis*, *Myrsine* (*Rapanea*) *melanophloeos*, *Xymalos monospora* and *Ilex mitis*, which were found more or less over the whole altitudinal gradient. *Macaranga capensis* var. *kilimandscharica* were very common up to 2300, but not above that elevation. *Syzygium guineense*, *Agarista salicifolia* (except one occurrence) and *Aphloia theiformis* were also found only below that elevation. *Bersama abyssinica* were found between 1840 - 2020 m a.s.l. *Schefflera goetzenii* were found in nearly all sites above 1860, *Olea europaea* above 2100 m a.s.l.

Erica excelsa occurred above 2160 m a.s.l. and *Podocarpus latifolius* in all sites but one above 2240 m a.s.l. Nine other species were found only in the distribution altitudes of *Erica* and *Podocarpus*, *Maytenus acuminata*, the often mentioned species *Hagenia abyssinica* with occurrence in only 6 sites, *Hypericum revolutum*, *Myrica humilis*, *Dombeya torrida*, *Clausena anisata*, *Peddiea fischeri*, *Prunus africana* and *Pittosporum goetzei*, all above 2430 m a.s.l.

More than half of the species occurred in 4 or less number of sites. It is difficult to have a strong opinion about the altitudinal distribution of species with such few occurrences. *Pittosporum goetzei* were found in one site at 2530 m a.s.l.

4.3 Stand structure

The sites within the Half-mile forestry strip were very influenced by man and in some places the forest was close to totally cut down with a basal area of less than 10 m^2 ha^{-1}.

4.3.1 Basal area and tree density

The basal area varied between 7 and 138 m^2 ha^{-1} with an average basal area for all sites amounted to just above 50 m^2 ha^{-1} and the averages for the three transects, Mweka, Kilema and Marangu of about 60.6, 45.7 and 48.0 m^2 ha^{-1}, respectively (Table 4). As pointed out the variation was very large with the extremely high value of over 138 m^2 ha^{-1} for site 8 at 1910 m a.s.l. along the Mweka transect and a few other sites with basal areas over 100 m^2 ha^{-1} along Mweka and Kilema transects. The variation in absolute terms in the forest parts of the transects was greatest along the Mweka and lowest along Marangu. The basal area in the forest diminished slightly with altitude (Fig. 2b) and was significantly correlated to sum of individual crown cover, crown depth and highest tree height (Table 5).

The stem density varied similarly great between 20 and 1080 stems ha^{-1}, with two extreme densities of 1600 and 3250 stems ha^{-1} (Table 4). Contrary to the basal area, the highest variation in density was measured along the Marangu transect and the lowest along the Mweka transect (Table 4). The density increased slightly with altitude (Fig. 2c) and was significantly correlated to crown cover, sum of individual crown cover and number of species (Table 5). A regression analysis with altitude as the independent variable and tree density as the dependent variable showed a significant linear relationship (R^2=0.107, p=0.048). That was the only significant relationship with either a linear or a quadratic model between altitude and the measured stand characteristics.

4.3.2 Crown projections (cover)

The projections on the ground of the crown areas could be measured and expressed as the area the tree crown projection covers of the investigated site area without looking at the crowns separately. This is usually expressed in percentage of the site area, in this case 1000 m^2. Alternatively, the sum of all the individual tree crown projections could be calculated, which naturally will be a higher figure, how much depends of the over-coverage of the separate tree crowns.

The horizontal projections of the crowns measured together varied between 10% and 90%, so in all sites there were openings between the crown projections (Table 4). As expected the crown cover in the HMFS were lower than in the forest above the HMFS and varied between 10 and 80%, and in the forest above the HMFS between (20) 30% and 90%. The crown cover diminished slightly with altitude (Fig. 2d). The average figures for the parts above the HMFS of the three transects were about 63, 69, and 66%.

Similarly to the other distributions the sum of the individual tree cover projections varied greatly both within the separate transect and between different sites within the same transect (Table 4). In all three transects the sites within the HMFS had lower coverage than in the forest above, especially the sites within the Kilema transect. In all sites above the HMFS but four, the sum of the projections of the individual tree crowns was higher than the site area of 1000 m^2. The sites along the Mweka transect had a slightly higher sum, between 0.8 and 4.6 times the site area (Table 4), than the two other transects, Kilema between (0.07) 0.2 and 3.3 (5.5) times the site area and the lowest sum was measured along the Marangu transect (0.07) 0.6 and 3.0 times the site area (Table 4). The mean values of all sites of the sum of crown cover projections above the HMFS was 2.4 times the ground area with average values for the three transects between 2.0 and 2.7. Individual sites had as high a value as times 4.6 the ground area (site 5 along the Mweka transect) and times 5.5 the ground area (site 13 along the Kilema transect). The sum of the individual tree cover projections diminished with altitude (Fig. 2e). The two measured variables of crown cover were highly correlated (Table 5). Sum of the individual crowns was also correlated with crown depth, and the two measured tree heights and as already mentioned with basal area and both variables with density. (Table 5).

4.3.3 Diameter distribution

Most tree individuals had a diameter between 10 and 20 cm (Fig. 4a). The diameter distribution showed a diminishing number with diameter size (Fig. 4a), a common distribution even if it is not a general distribution in natural forests (Hytteborn *et al.* 1987). In total 46 tree individuals had a diameter over 1 m. One tree individual, a *Cordia africana*, had the very impressive diameter of about 3.11 m, and further 15 tree individuals of *O. usambarensis*, 10 of *S. goetzenii*, 7 of *I. mitis*, 4 of *A. salicifolia*, 2 of each *S. myriantha* and *X. monospora*, and finally 1 individual each of *M. capensis*, *P. fischeri*, *P. fulva*, *P. latifolius*, *S. guineense* had diameters over 1 m. These big trees were unevenly distributed among the three transects and with altitude. Most big trees were found along the westernmost transect, Mweka and fewest along Marangu transect (Fig. 5a). Along Marangu transect most big trees were found at rather low elevation, between 1860-2020 m a.s.l. and at the highest situated site at 2620 m a.s.l. Along the two other transects most big trees were found at intermediate altitudes, along Mweka between 1910 and 2500 and at 2740 m a.s.l., and along Kilema transect at 1870-1930 m a.s.l. but with big trees spread along the whole transect, both at the lowest site at 1780 m a.s.l. and the highest site at 2670 m a.s.l., respectively (Fig. 5a).

Most of the sites along transect 1 had a diameter distribution with a diminishing number from the smallest diameter class to the biggest (Fig. 5a). The exception is sites 106, partly 102 and 107, 110-113 and 118. The first four sites along transect 2 had very few tree individuals. Most of the sites along Kilema transect had a lower number of individuals in the smallest diameter class than in the next class, namely 205, 207, 210-219 (Fig. 5a). The same was true for site 301, 304-305, 309-310 and 316 along Marangu transect. Sites 313 and 314 were dominated by *Erica excelsa* and with a very narrow diameter distribution and an extremely high density. Site 315 had only 2 tree individuals (Fig. 5a).

4.3.4 Tree height distribution

Few of the individuals defined as trees were below 5 m (Fig. 4b). Most tree individuals were between 5 and 10 m and up to 20, but many were as high as 35 m. The height of the highest tree, a planted individual of *Eucalyptus saligna,* was estimated to be 50 m. There were more trees in the height class 15 to 20 m than in the class 10 to 15 m otherwise the tree numbers successively diminished with increasing size (Fig. 4b).

Even with so broad width of the height classes as 5 m, there were very little common distributions between the sites (Fig. 5b). It is very difficult to find any regular patterns in the tree height distributions along the altitude. All types of distributions could be found, from close to normal to negatively and positively skew to completely irregular. Again the two sites (313, 314) dominated by *Erica excelsa* showed a diverging pattern compared to most other sites (Fig. 5b), with most trees in low height classes. The two measured tree height variables were correlated with each other and with the crown depth (Table 5). The highest tree height was negatively correlated with altitude. This variable was the only significant correlation with altitude. As already mentioned the highest tree height was positively correlated with basal area, sum of individual tree crowns, but the mean height additionally only with the sum of individual tree crowns.

4.3.5 Crown depth and area

The crown depth distribution of the total tree populations showed a diminishing pattern with increasing size, except in the two first classes with fewer individuals in the class up to 5 m than in the class 5 to 10 m (Fig. 4c). The crown depths of individual trees varied very much from a few meters to 40 m (Fig. 5c). The highest crown depth was 39 m of an *Ocotea* trees. Individuals of *Ocotea, Ilex*, *Podocarpus, Syzygium* and *Xymalos* had estimated crown depths over 30 m. In stands with high tree stems it is possible with deep crowns, which of course is not possible of low trees or in sites with a low total height of all the trees. However, most sites have trees higher than 25 m (Table 4). Several of the sites in the Half-mile forestry strip and the four sites dominated by *E. excelsa* (site 118, 220, 313 and 314) had few height classes of crown depths (Fig. 5c). As already mentioned crown depth was correlated with basal area, sum of individual crowns and the two measured variables of tree heights (Table 5).

The crown depth distributions varied very much with close to normal (sites 105, 211, 216, 220, 308, 310), positively skewed (e.g. 103, 109, 111, 207, 303) or negatively skewed (e.g. 106, 213, 301) (Fig. 5c). Number of classes of crown depth diminished with altitude (Fig. 2g).

The estimated projections of the crown areas also showed a high variation. The big tree individual of *Cordia* with the largest measured stem diameter also had the largest crown area with an estimated projection of slightly over 1000 m^2. Further ten individuals of the species *Ilex*, *Polyscias*, *Ocotea*, *Syzygium*, *Macaranga*, *Schefflera goetzenii*, had an estimated crown projection of over 500 m^2 and 94 individuals had an area larger than 200 m^2 which also included the species *Agarista salicifolia*, *Eucalyptus saligna*, *Hagenia abyssinica*, *Nuxia congesta*, *Peddiea fischeri*, *Podocarpus latifolius*, *Schefflera myriantha*, *Syzygium guineense, Tabernaemontana stapfiana* and *Xymalos monospora*. However, most of the individuals had a very small estimated crown projection. More than 2100 of the measured individuals had a crown projection of less than 100 m^2.

All except site 213 had more or less the same type of distribution of crown cover projections, positively skewed, with most individuals in the smallest class. Sites with at least some stems with a larger crown area were 102, 104 - 109, 113 – 114, 209, 211, 214, 216 – 217 and 302. All except one of these sites had a lower tree density than the average site density, if the heavily influenced sites in the HMFS are excluded.

4.3.6 Trunk shape

Straight stems were in majority of the four categories, but the total sum of bent and crooked stems were higher than the number of the straight stems (Fig. 4d). It was so even if the number of leaning, but straight stems were added to the straight stems (1409 of the 2384 stems). There were in all sites at least some straight stems and the three stems in site 203 and the two stems in site 315 were all straight (Fig. 5d). Otherwise there were in all sites some leaning, bent or crooked stems. In about half of the sites (25 of 54) the majority of stems were straight and in 13 and 16 sites, respectively, the majority of the stems were bent or crooked.

In 14 of the 18 sites along Mweka transect straight stems were dominating, but along Kilema transect bent stems dominated in 11 of 20 sites and finally along Marangu transect straight stems dominated in as many sites (10) as crooked stems did (Fig. 5d). It is not likely that this result with a dominance of straight stems in Mweka transect, dominance of bent stems in the central transect and dominance of crooked and bent stems together in Marangu transect is an artefact resulting from a change in interpretation during the fieldwork.

Dividing the stems in only two categories, straight and leaning as one group, as they both had a straight stem and combining bent and crooked in the other gave a somewhat different result. 19 sites were dominated by straight and leaning stems and the rest, 34 were dominated by bent and/or crooked stems. One site had equal numbers in the two groups.

4.3.7 Buttress

Only 17 stems of the whole sampled tree population of 2384 tree stems had buttress, nine *Ocotea usambarensis* (5 individuals in site 108, one each in sites 112 and 113 and two in site 216), two *Schefflera goetzenii* (one each in sites 113 and 210), two *Allophylus africanus* (both in site 208), one *Cordia africana* (site 210), one *Macaranga kilimandscharica* (site 302), one *Bersama abyssinica* (site 304), and one *Olea europaea* (site 309).

4.3.8 Climbers and epiphytes

Epiphytes have a very import function in the water balance in the forest. We found that there are some differences regarding the epiphytic cover according to height, size of trees and location. Similarly climbers and vines are an important and characteristic feature of many tropical forests.

4.3.8.1 Climbers and vines

Most stems had no or an insignificant coverage of climbers and vines (Fig. 4e). However, in every site at least some trees were covered with climbers or vines (Fig. 5e). In the centrals parts of Kilema and Marangu transects there were a higher percentage of classes with higher coverage of climbers/vines than at low altitudes or close to the upper forest border. But climbers/vines were more frequent at low altitudes than vascular epiphytes (cfr. Figs. 5e, f).

4.3.8.2 Vascular epiphytes

There were more trees in cover class 1, with a coverage of vascular epiphytes up to 10%, than in cover class 0, with no or an insignificant amount (Fig. 4f). The number of trees decreased successively in the higher classes with rather few trees having a high coverage of vascular epiphytes (Fig. 4f). Vascular epiphytes were found along all three transects and in all sites, from the lowest to the highest situated (Fig. 5f), but mostly with a coverage below 25% of the stem. A few stems in some of the sites as site 113 and the site situated higher than 2600 m a.s.l. along Mweka transect, sites between 1910 and 2050 m a.s.l. (sites 210-214) along Kilema transect and sites between 2100 and 2459 m a.s.l. (sites 305-312) along Marangu transect had a high cover of vascular epiphytes (Fig. 5f).

4.3.8.3 Epiphytes of bryophytes and lichens

The distribution of cover classes (0-5) of bryophytes and lichens on tree stems had a completely different form than the distributions of cover classes of climbers/vines and vascular epiphytes (Fig. 4g). Most common were cover class 3 with coverage between 25 and 50% of the stems. Fewest individuals were found with cover class 0 with no or an insignificant amount of bryophytes/lichens. In the lowest situated sites in all three transects the class(es) with no or low coverage of bryophytes/lichens dominated (Fig. 4g). Site 102 at 1610 m a.s.l. had nearly no bryophyte/lichens on the 19 stems (Fig. 5g). From site 108 at 1910 m a.s.l., site 206 at 1850 m a.s.l. and site 305 at 2100m a.s.l. up to the tree line, tree numbers within the class with the relative frequency of 3 or higher dominated the distribution (Fig. 5g). As already mentioned sites 201-204 and 315 had very few stems.

4.4 Individual tree species characteristics

Nine species in the data set had such a high number of individuals, more than 50 individuals that it is worth to search for some general patterns in their characteristics. Here we treat the same type of characteristics as we did in describing the different sites.

4.4.1 Elevation distribution

There were over 600 individuals of *E. excelsa* in the data set (Appendix 3).. The species occurred mainly in the upper part of the forest (Fig. 3), where it constituted a belt, probably mostly established after fire (Hemp and Beck 2001, Hemp 2006b). However it also dominated or had an important part of the tree population in sites at lower elevation in the Mweka transect at site 15 (2600 m a.s.l.) and in the Marangu transect at sites 6 and 8 (2160, 2280 m a.s.l.), besides the higher sites 118 (at 2860 m), 220 (at 2670 m) and 313-314 (at 2540, 2580 m), where the species probably established after fire. *E. excelsa* did not occur in the two highest sites in the Marangu transect.

Ilex mitis was found more or less over the whole altitudinal gradient (Fig. 3) but the species never dominated any site. It was found in slightly less than half (22) of the sites (Fig.3). There were only 59 individuals of *I. mitis* in the data set (Appendix 3).

The 169 individuals of *Macaranga capensis* var. *kilimandscharica* in the data set (Appendix 3) were restricted to the lower part of the three transects (Fig. 3). It was a dominant species in the HMFS or close to that.

During the registration 71 individuals of *Myrsine melanophloeos* were found (Appendix 3). The species was distributed over the whole altitudinal gradient (Fig. 3). It was frequent in one of the sites along Marangu transect dominated by *Erica*.

Ocotea usambarensis were a rather common species with 204 individuals in 19 sites (Appendix 3). It was found especially along the Mweka transect with occurrences over the whole transect, but with dominance in the middle part of the altitudinal gradient (Fig. 3). In the two other transects it had a scattered occurrence. Very few individuals were found in Marangu transect.

There were only 65 individuals of *Olea europaea* subsp. *cuspidata* in the transects (Appendix 3). It occurred in the upper part of the forest, 2100 – 2740 m a.s.l., mostly in Marangu transect (Fig. 3), where it occurred in some sites with an intermediate number.

Podocarpus latifolius was one of the most common species in the data set (Appendix 3). It occurred in 23 sites, all but one site from 2240 m a.s.l. and upwards (Fig. 3). It formed a rather distinct belt and dominated or co-dominated many of the sites above this altitude and occurred in all three transects in many of the sites.

There were over 148 individuals of *Schefflera goetzenii* in the data set (Appendix 3) and it occurred in most sites from 1860 m a.s.l. and upwards and in all three transects (Fig. 3). It dominated few sites, but was well distributed with occurrence in 32 sites.

Xymalos monospora was after *E. excelsa* the most frequent species in the data set with 394 individuals (Appendix 3), but contrary to *Erica* it occurred in many of the sites, 40 of 49 (Fig. 3).

4.4.2 Diameter distributions

Six of the nine selected species had most individuals in the smallest diameter class (Fig. 6a). *Macaranga*, *Ocotea* and *Schefflera goetzenii* had more trees in the next smallest class. In most cases the numbers of individuals in the classes successively decreased with larger diameter. *Erica*, especially, had a very narrow distribution with many stems in the smallest classes and few really big individuals. The diameter distribution of *Olea* and of *Myrsine* was also narrow, but with less dominance of individuals in the smallest class than *Erica*. These three species also had no tree with a large diameter. All the other species had individuals with diameters over 1 m. Several of the species had individuals with very large diameters, as *Macaranga*, *Ocotea*, and *Podocarpus*. In the large diameter classes the numbers were irregular, as expected. It is difficult to have any opinion if that is because of disturbance from man (forestry) or because of irregular natural disturbance, such as windfall.

Xymalos had an even diminishing diameter distribution.

4.4.3 Height distributions

No individuals of *Erica excelsa* reached higher than about 25 m (Fig. 6b). The other species had individuals, which reached at least 30 m and individuals of *Ocotea*, *Olea* and *Podocarpus* reached 40 m or close to that. The height distributions of *Erica* and *Xymalos* were positively skewed with many short individuals and progressively fewer individuals in the higher classes, similar to the diameter distributions. The height distributions of *Myrsine* and *Schefflera goetzenii* were similar to normal distribution. In the other species the height distributions varied among the species, but with few individuals in the highest class.

4.4.4 Crown depth and area

Naturally, the short *Erica* can not have deep crowns and only two individual had a crown depth of about 20 m (Fig. 6c). The species, *Ilex*, *Ocotea* and *Podocarpus* with many high individuals had some individuals with deep crowns over 30 m. The distributions varied, but that of *Myrsine* and *Ocotea* were similar to normal. Other species, such as *Erica*, *Macaranga*, *Olea*, *Podocarpus* and *Xymalos* had a positively skewed distribution, but *Schefflera* a distribution tended to be negatively skewed.

The distributions of the crown area projections were in all nine species positively skewed (Fig. 6d). Many individuals had very small crowns and few tree individuals had a large crown area. The crown diameters of *Erica*, *Myrsine* and *Olea* were all small with no large spreading crowns. *Ilex*, *Macaranga*, *Ocotea*, *Podocarpus*, *Schefflera goetzenii* and *Xymalos* had some individuals with very large crown area projections over 200 m^2, 8, 7, 29, 4, 21 and 10 individuals, respectively. One individual of *Ilex* had a crown area projection of over 900 m^2, *Macaranga*, *Ocotea* and *Schefflera goetzenii* one individual each of ca 700 m^2.

4.4.5 Trunk shape distribution

A majority of the stems of *Erica* were either bent or crooked (Fig. 6e). The same was true for *Ilex*, *Schefflera goetzenii* and *Xymalos*. In the other tree species the majority had straight stems, but all trunk shapes were represented, except that *Ocotea* did not have any leaning stems.

4.4.6 Climber and vine distribution

The amount of ‘climber and vine’ was positively skewed for all tree species with almost no coverage or a cover of less than 10% on most stems and a successively less number of stems with the higher cover degrees (Fig. 6f). However, *Schefflera* had a distribution towards normal with more stems in the cover class between 25 and 50 % than in the other cover classes. The distribution of ‘climber and vine’ on *Ilex* was irregular.

4.4.7 Vascular epiphyte distribution

Most of the stems of the nine selected species were covered with ‘vascular epiphyte’ to a lesser degree than 10 %, but all species had at least some individuals with coverage between 50 and 75 % or even higher (Fig. 6g). No individuals of *Ocotea usambarensis* had coverage higher than 50 % and the cover class between 0 and 10 % dominated. In two species, *Olea* and *Schefflera goetzenii*, the cover class between 10 and 25 % were more numerous than any of the other cover classes.

4.4.8 Bryophyte and lichen distribution

The distribution of the cover classes of 'bryophyte and lichen' on most of the nine selected species differed from the distributions of 'climber and vine' and 'vascular epiphyte' by higher frequency in the higher cover classes (Fig. 6h). In many species the distribution was negatively skewed with many tree individuals in one of highest cover classes, e.g. *Ilex*, *Ocotea*, *Podocarpus*, *Schefflera goetzenii* and *Xymalos*. The distribution on *Erica* was close to a normal distribution. More stems of *Macaranga* were in the cover class 1 (up to 10 %) than in any other cover class. The number of stems of *Myrsine* was rather evenly distributed over the different cover classes, except the lowest and the highest cover classes. The cover class 3 (coverage between 25 and 50 %) dominated in the populations of *Olea*.

5 Discussion and Recommendation

In this study a possible methodology for fieldwork and presentation of qualitatively and quantitatively description of the structure of the forest in the context of catchment forest is explored.

5.1 On methods

The study shows that it is possible to do a field inventory of the structure of a montane, moist forest with uncomplicated instruments and measures, and produce data and results which can be analysed in order to get a comprehensive description of the forest structure. By knowing the tree species and doing simple measurements and calculations, it is possible for foresters and local experts to carry out a similar field study. Ecologist and other professionals can support on design and development of inventory procedure and use date for further analyses.

The complexity, the seemingly unstructured appearance of the fixtures and large scale of the forest is a challenge for the reliability of the selection of sites and practical execution of measurement. The most reliable measure is DBH. The measuring error regarding tree height and the covering of crown and epiphytes is not analysed. For future inventories a percentage scale, and not geometric classes, should be considered. Also to delineate and form the rectangular form of the plots, demands efforts. Another form could be a circle, but we found that it is difficult even to draw the arc by using measuring tape from a centre.

The challenge of ecological inventories and transformation of data to information and knowledge on environmental operational level is to balance time consumption of fieldwork and data processing on one hand, and scientific substance, validity and reliability on the other.

Selection of sites will often depend on a professional judgement, and in this case we have tried both to cover the variation along the altitudinal gradient and a East-West gradient, in addition to cover both the very human affected areas of the lower part of the forest as well as the more untouched parts higher up.

5.2 On results

The results of the analysis is described and partly discussed in the chapter 4. Generally the results showed less difference according to altitude and position then was expected, except the difference between the heavily disturbed sites in HMFS and some sites at higher altitude dominated by *Erica*.

It is possible, however, from the results, to select sites where the forest structure is rather intact and less affected by humans. These sites can be used to define a forest quality standard which can be used as basis for assessing how far from a well developed forest structure other sites are. These data can be transformed further to proximity-to-target indicator, and to serve as a kind of benchmarking between the sites.

5.3 On application of results

The purpose of the study was to explore a possible methodology for improving some aspects of the ecological qualities of the forest in order to do better management and decision making where the local society could participate in genuine way, and based the overall goals for catchment forest management.

The challenge of ecological inventories and transformation of data to information and knowledge on environmental operational level is to balance time consumption of fieldwork and data processing on one hand, and scientific substance, validity and reliability on the other.

Types of application can be diversified into: a) thematic mapping activities b) input to hydrological models, and c) integration of local understanding of the status and quality of the forest for ecological services provided by the ecosystem and corollary management opportunities.

For ground truth investigation for remote sensing (aerial photo and satellite image interpretation) this kind of study will give more details than the image could show. Probably a parallel study of signature of the images and photos could be complimentary and give more accurate information and for larger areas, for a multipurpose management approach. For mapping and development of land use map the same aspects as mention above, could be regarded.

To produce input to hydrological models there is a need for more knowledge about the quantitative aspects and contributions from the different forest types and sites (or mapping units). This application requires detailed and time consuming investigation of how the selected variables are affected by and affects the hydrology in the forest.

For local involvement, management and learning the applied inventory method could increase the local participation, due to the possibility to take part in process for defining status and quality of the forest. Transferring ecological data to indicator system can create an arena for mediation of knowledge This require that local forest management is organized in a way that the involvement seems meaningful and gives responsibility for long term and sustainable management approach to the affected stakeholders is acknowledged.

5.4 Stand structure

We measured the projections of the crown, not the cover. The later characteristics will naturally give a lower figure as there also in these crowns are openings within the crowns.

The origin and history of the management regimen of the 'Half-mile forestry strip', logging, and fire wood collecting, other kind of utilisation and encroachment of the forest is discussed in Newmark (1991, 2002).

In this study a possible methodology for fieldwork and presentation of qualitatively and quantitatively description of the structure of the forest in the context of catchment forest is explored.

The material collected and analysed so far shows that by measuring and estimating a few parameters it is possible to achieve ecological data and information that partly can contribute to the development of a possible assessment scheme of catchment properties of forested land. This can be developed further to characterise and justify mapping units for land use maps or aerial photo interpretation. It may also constitute the basis for development of parameters on forest structure in the context of hydrological models.

The challenge of ecological inventories and transformation of data to information and knowledge on environmental operational level is to balance time consumption of fieldwork and data processing on one hand, and scientific substance, validity and reliability on the other.

Hall (1991) investigated the method of multiple-nearest-tree sampling in an ecological survey of catchment forest in East Usambara, Tanzania.

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Legends to the Figures in

Structural characteristics of the montane, moist forest on the southern slopes of Mt Kilimanjaro, Tanzania.

Figure 1. Map over Mt. Kilimanjaro in northern Tanzania showing the forest reserve and the three investigated transects, Mweka, Kilema and Marangu.

Figure 2. Relationship between altitude (m a.s.l.) and a number of forest characteristics in 54 investigated sites (1000 m^2) along three transects Mweka, Kilema, and Marangu on the southern slopes of Mt Kilimanjaro (DBH ≥ 10cm). The transects started at the lower border of the so called Half-mile forestry strip and ended at the upper forest limit;

a. number of tree species, b. basal area ($m^2 ha^{-1}$), c. density (number of stems ha^{-1}), d. crown cover (%), e. sum of individual tree crown projections ($m^2 ha^{-1}$), f. height of highest tree (black circle) and average tree height (open circle) (m), g. average crown depth (m).

Figure 3. Tree species distribution (N=49) along three altitudinal transects, Mweka (Mw), Kilema (Ki), and Marangu (Ma) investigated in 54 sites on the southern slope of Mt. Kilimanjaro. To the left the distribution of the sites among the three transects is shown. Shortenings of the names of the species see Appendix 3.

Figure 4. Distributions of structural characteristics of the measured tree population, (DBH ≥ 10 cm) (n= 2384), in 54 sites along three transects, Mweka, Kilema and Marangu, in the forest on Mt. Kilimanjaro. The studied sites were distributed, from the lower border of the so called Half-mile forestry strip and ended at the upper forest border.

Numbers of tree stems in different size classes or in classes of other types:

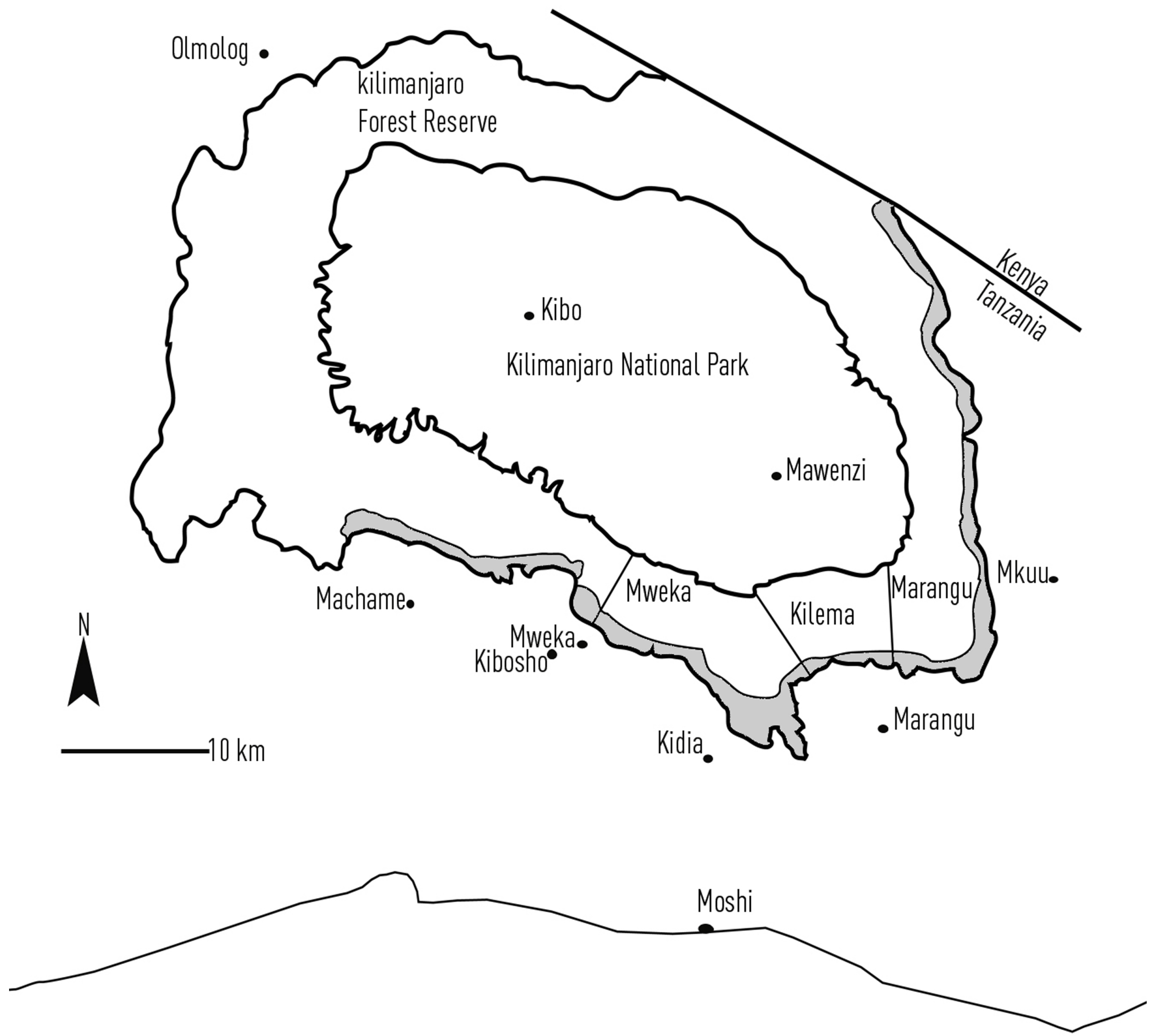
a. diameter distribution (m), b. height distribution (m), c. crown depth (m), d. trunk shape (0 straight, 1 leaning, 2 bent, 3 crooked), e. climbers and vines (0: almost nothing, 1: <10% cover of the tree stem, 2: 10 < 25%, 3: 25 < 50%, 4: 50 < 75%, 5: ≥75%), f. vascular epiphytes (explanations, see climbers/vines), g. bryophytes and lichens (explanations, see climbers/vines).

Figure 5. Relative distributions of characteristics of the tree population (DBH ≥ 10 cm), in 54 sites along three transects, Mweka, Kilema and Marangu, in the forest on Mt. Kilimanjaro, from the lower border of the so called Half-mile forestry strip to the upper forest limit;

a. diameter distribution (m), b. height distribution (m), c. crown depth (m), d. trunk shapes (explanations, see legend to Fig. 4), e. climber and vines on trees, (explanations, see legend to Fig. 4), f. vascular epiphytes, (explanations, see legend to Fig. 4), g. bryophytes and lichens as epiphytes, (explanations, see legend to Fig. 4). Sites 201-204 along Kilema transect, and site 315 along Marangu transect had too low numbers of tree stems to be included in a, b, c.

Figure 6. Relative distributions of characteristics of nine tree species, *Erica excelsa*, *Ilex mitis*, *Macaranga kilimandscharica*, *Myrsine melanophloeos, Ocotea usambarensis*, *Olea europaea, Podocarpus latifolius, Schefflera goetzenii* and *Xymalos monospora* (DBH ≥ 10 cm), in 54 sites along three transects, Mweka, Kilema and Marangu, in the forest on Mt. Kilimanjaro, from the lower border of the so called Half-mile forestry strip to the upper forest limit;

a. diameter distribution (m), b. height distribution (m), c. crown depth (m), d. crown area, e. trunk shapes (explanations, see legend to Fig. 4), f. climber and vines on trees, (explanations, see legend to Fig. 4). g. vascular epiphytes, (explanations, see legend to Fig. 4), h. bryophytes and lichens as epiphytes, (explanations, see legend to Fig. 4).


Olmolog
kilimanjaro
Forest Reserve
Kibo
Kilimanjaro National Park
Kenya
Tanzania
Mawenzi
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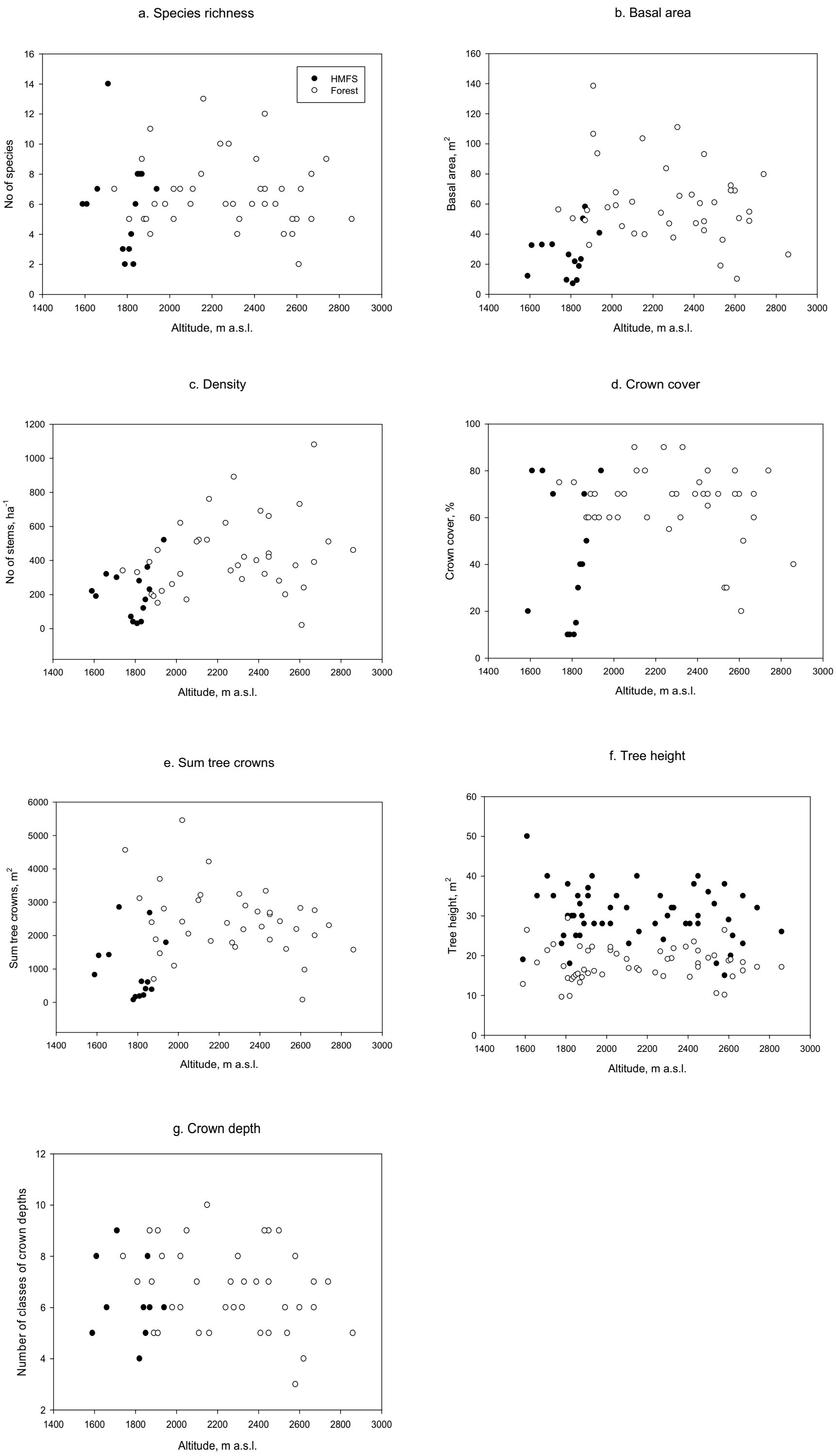
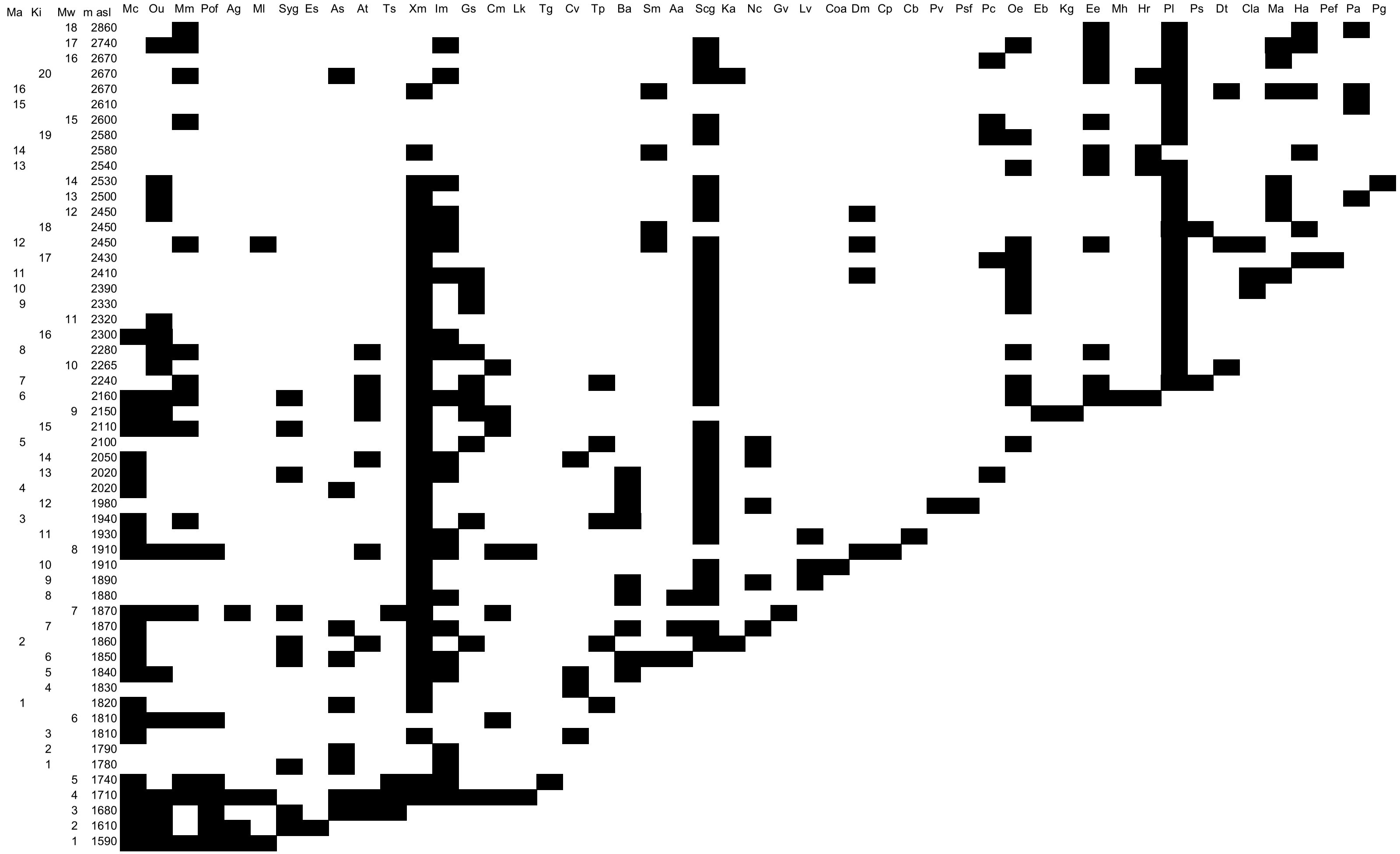


Fig. 2a-g. Relationships between altitude and a number of forest characteristics.

Fig. 3. Tree species distribution along altitude.



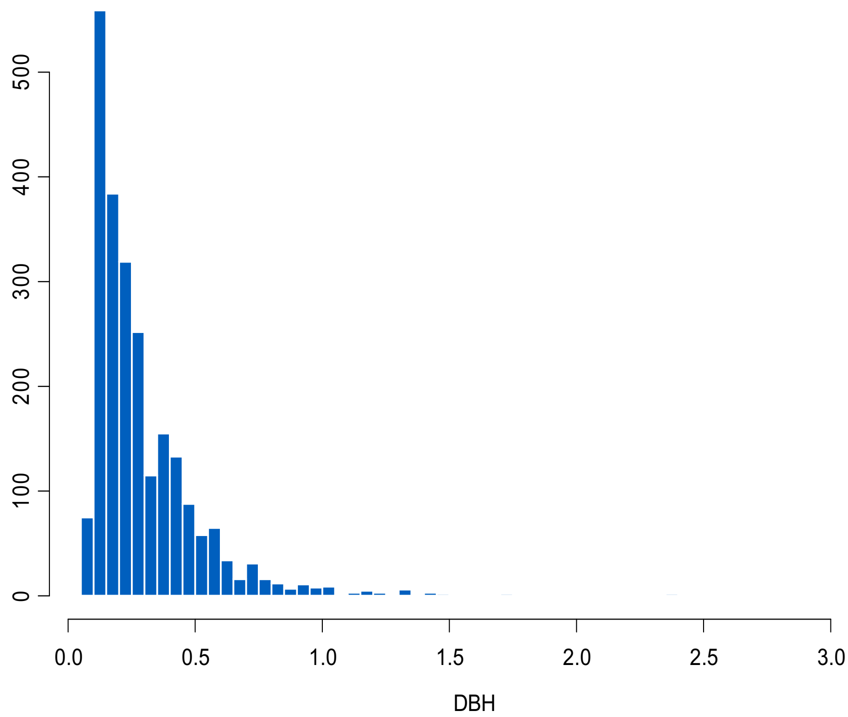


Fig. 4a. Diameter classes

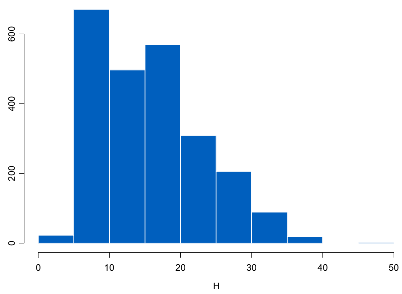


Fig. 4b. Height classes

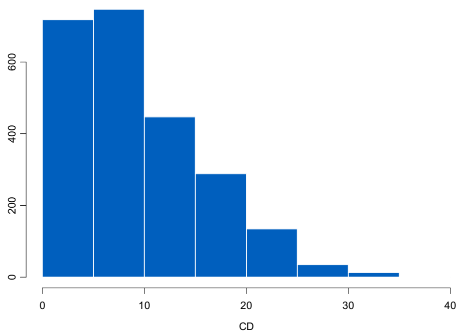


Fig. 4c. Crown depth

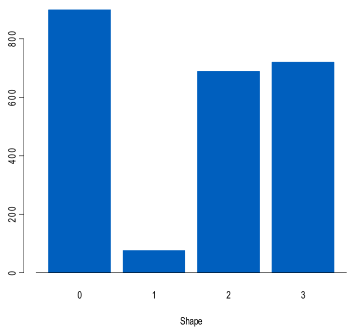


Fig. 4d. Trunk shape

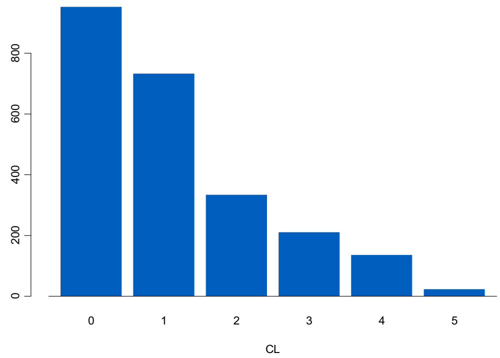


Fig. 4e. Climbers and vines

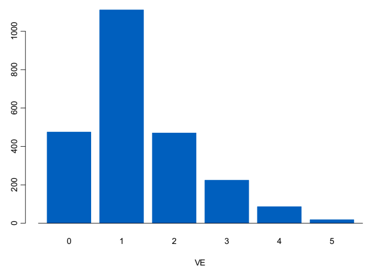


Fig. 4f. Vascular epiphytes

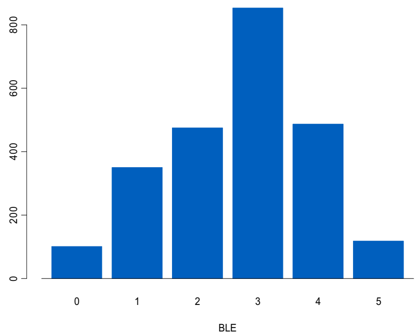
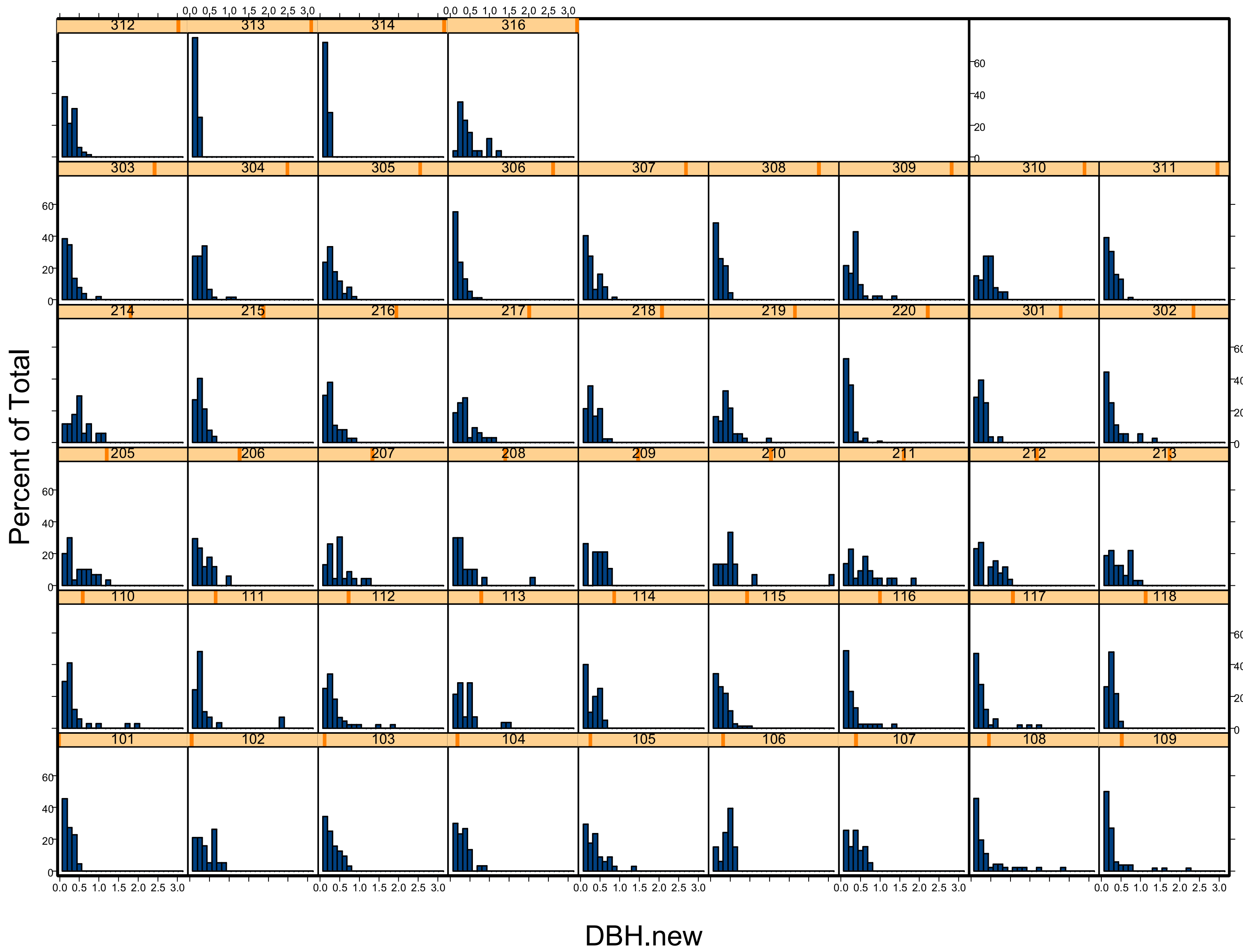


Fig. 4g. Bryophytes and lichens.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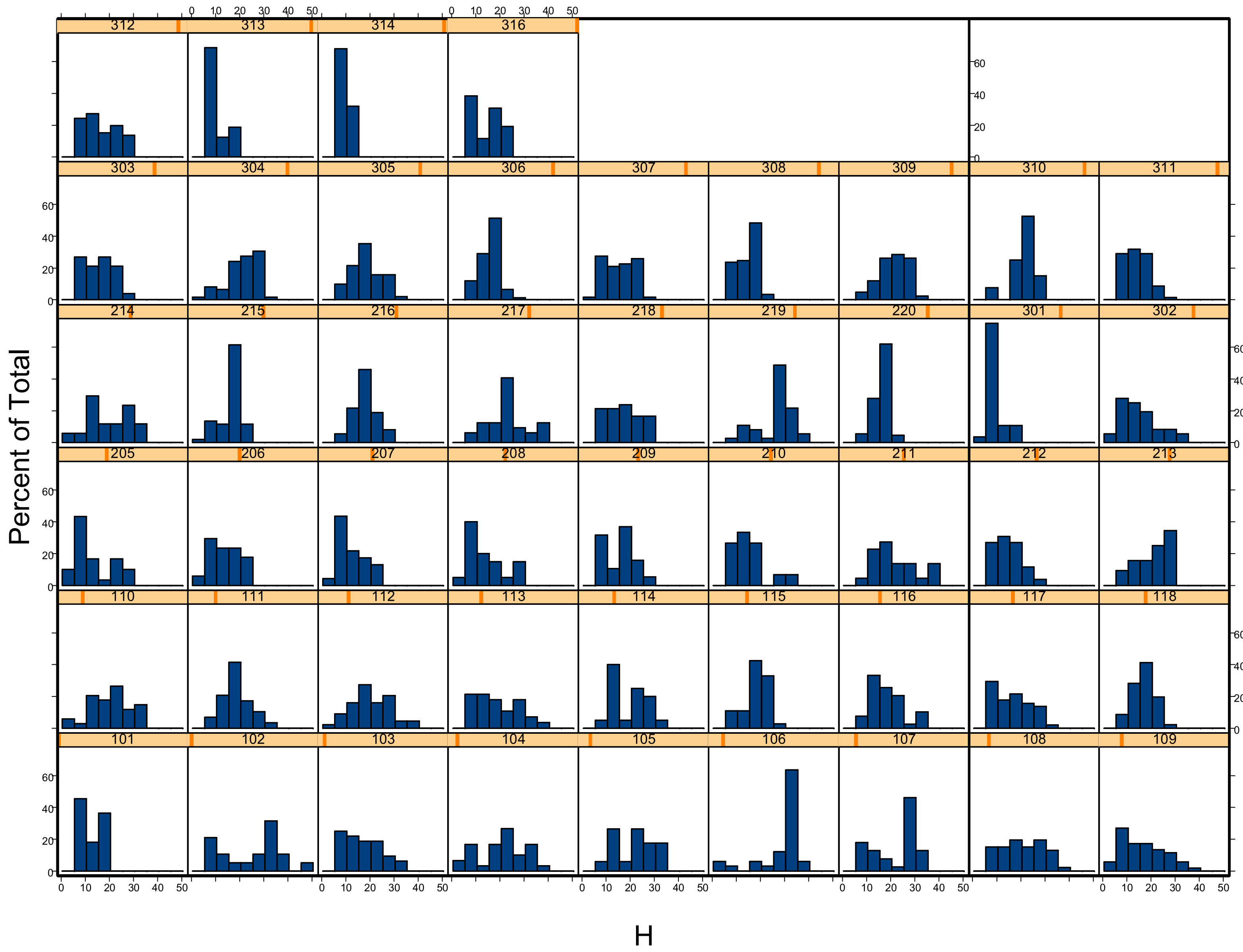
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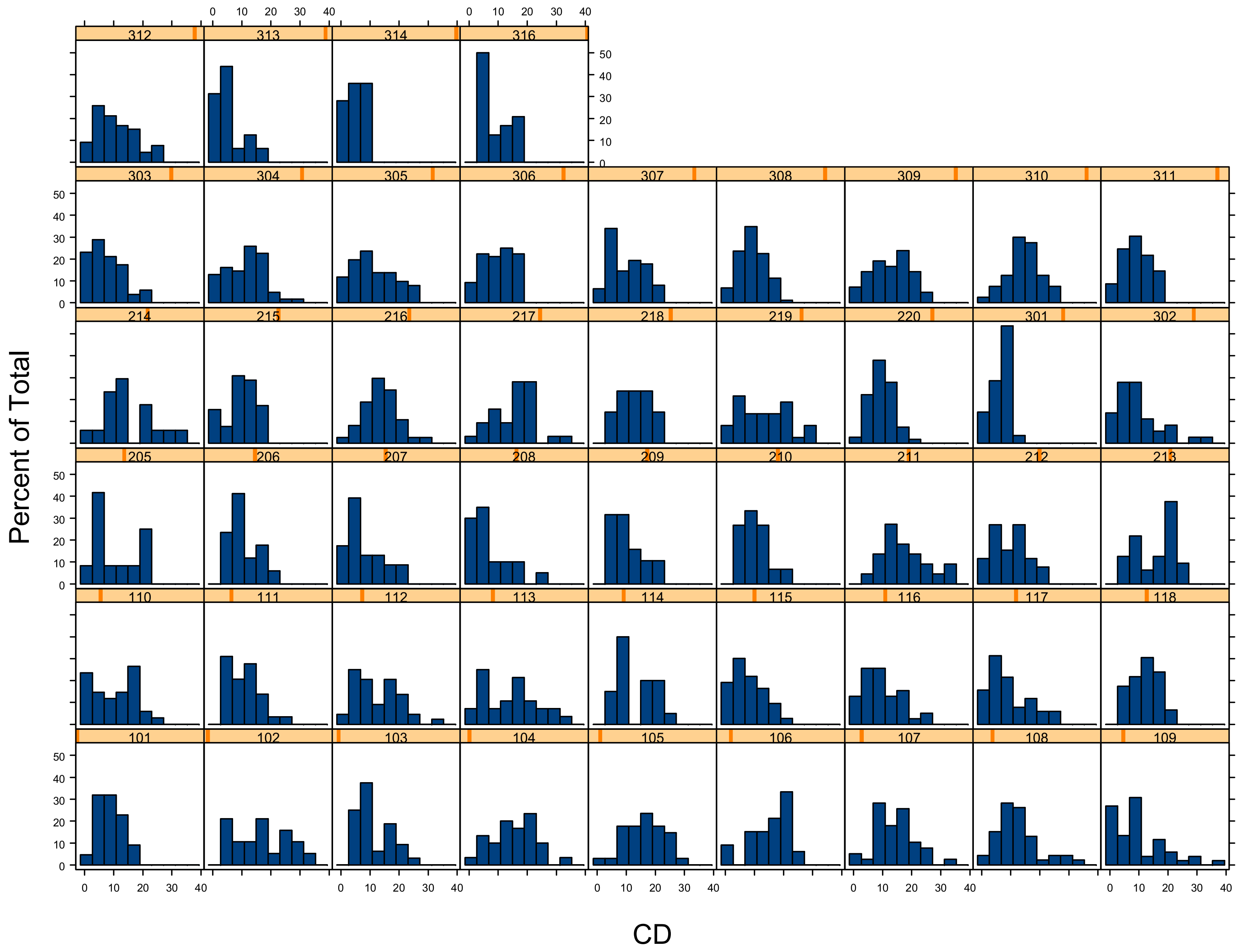
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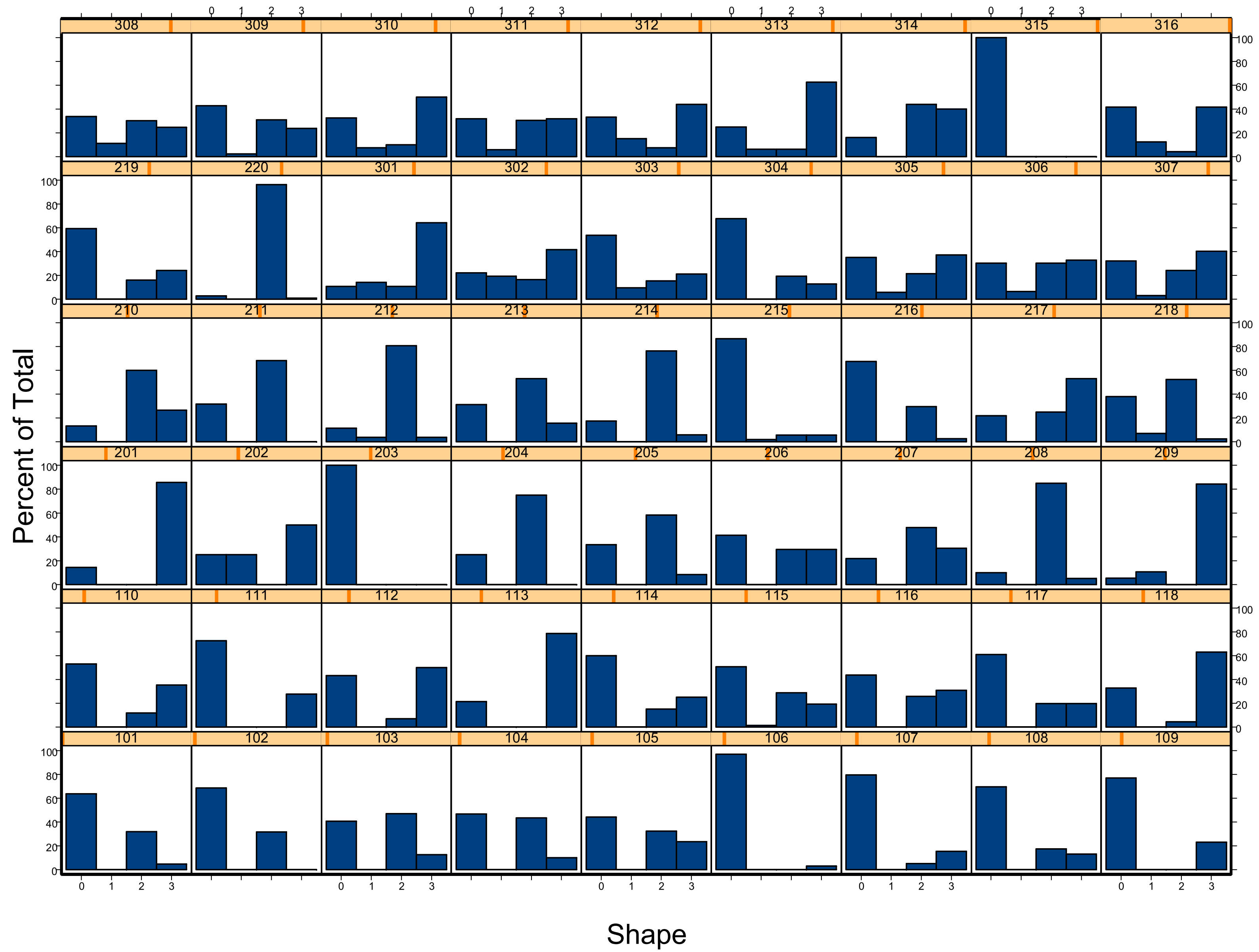

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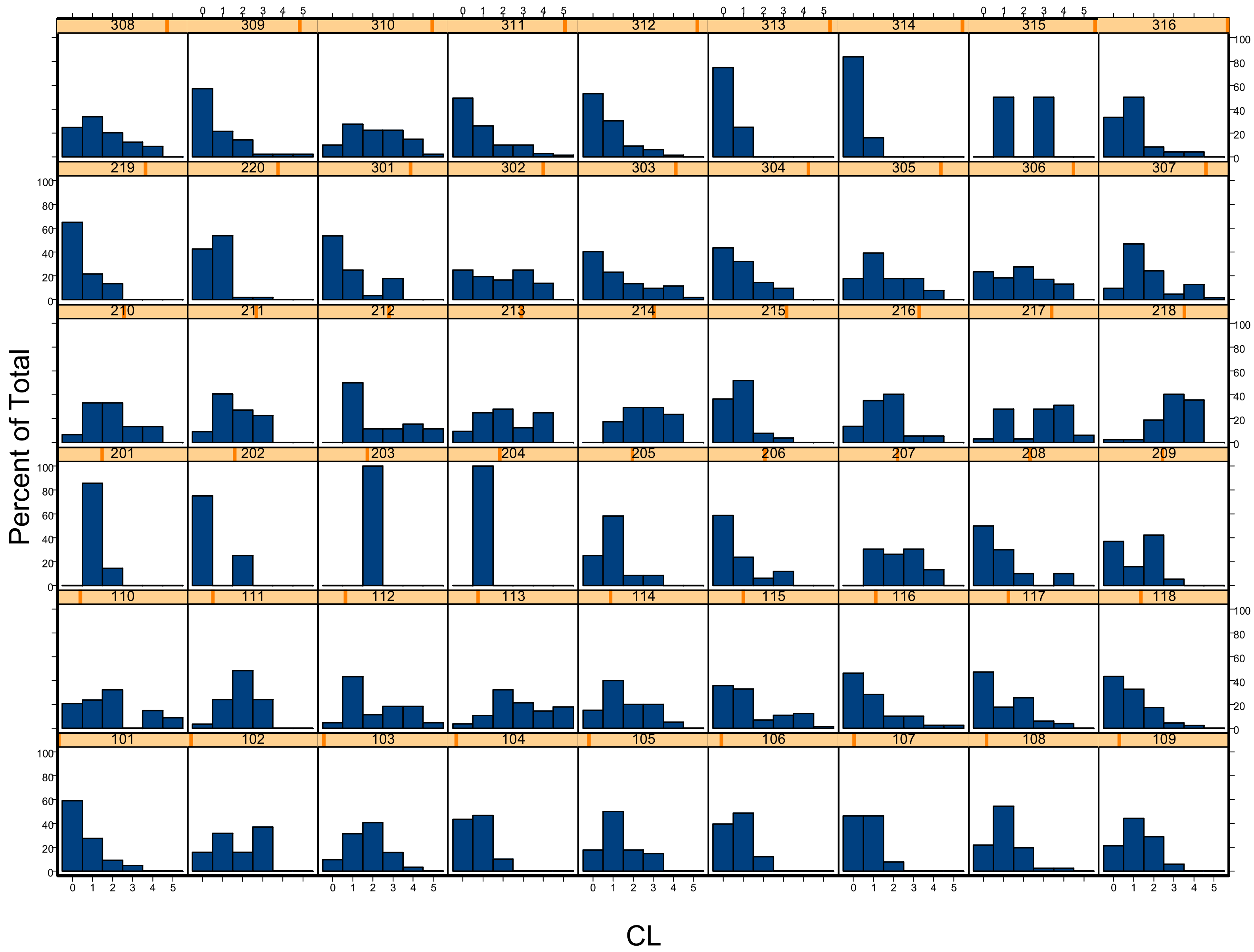
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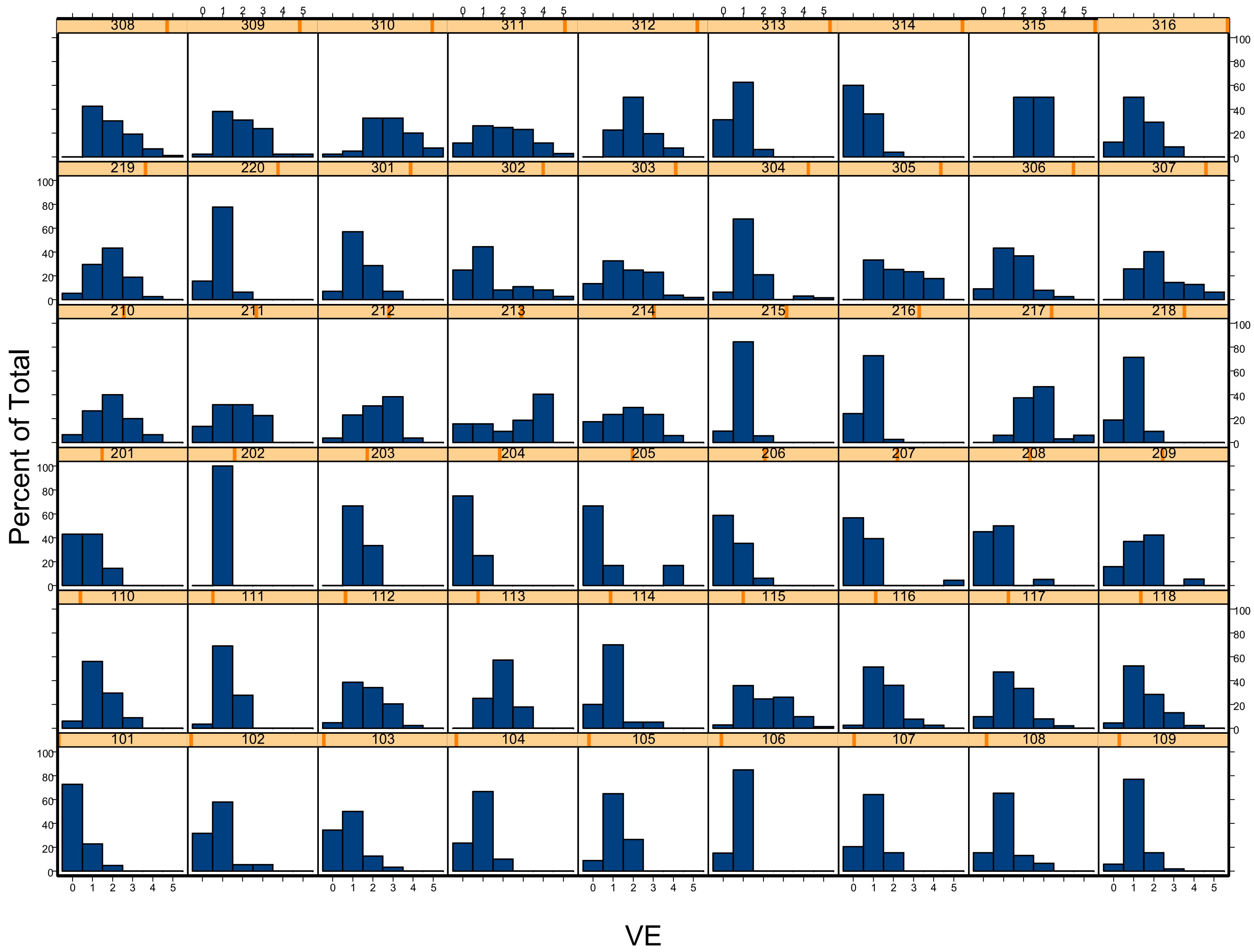

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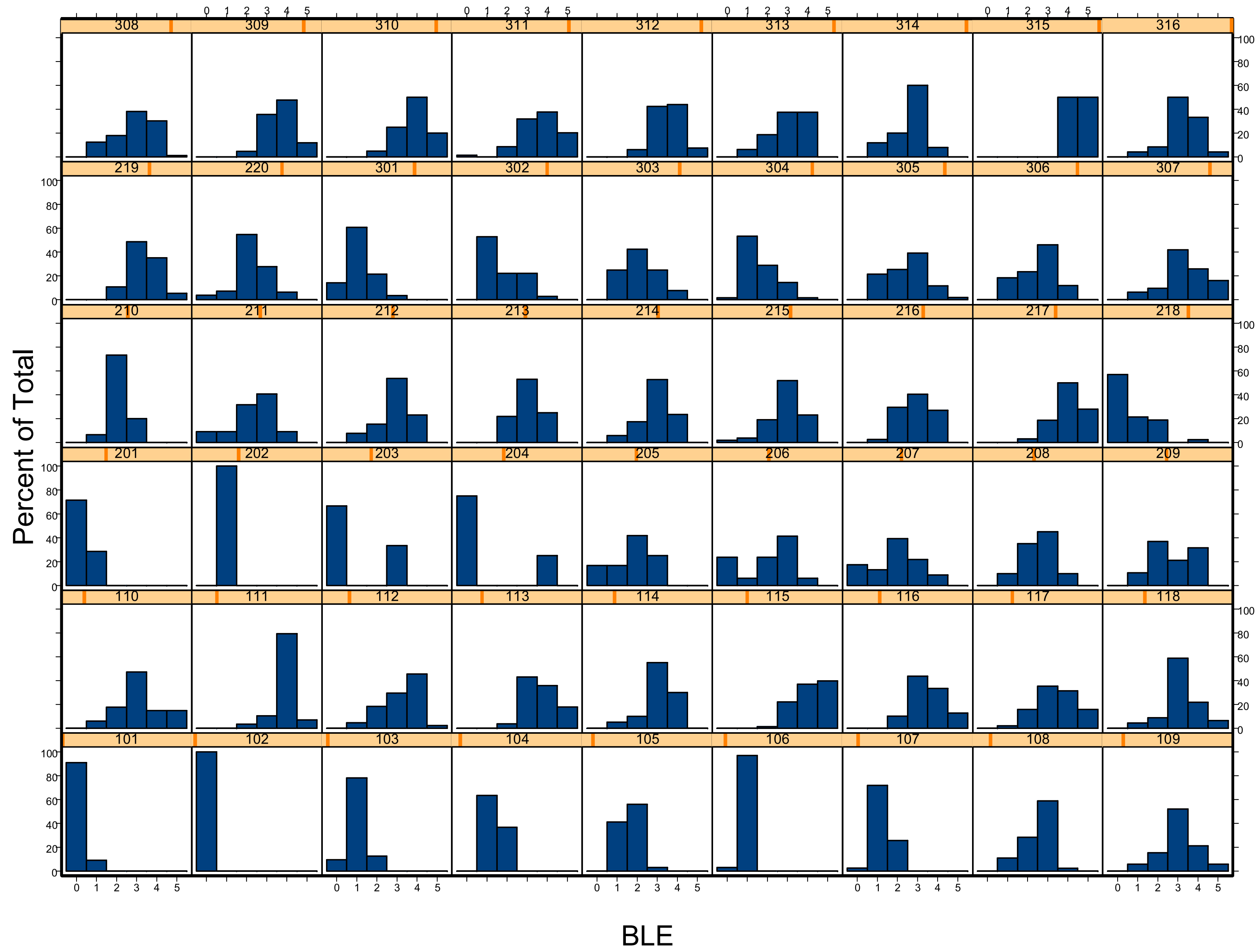

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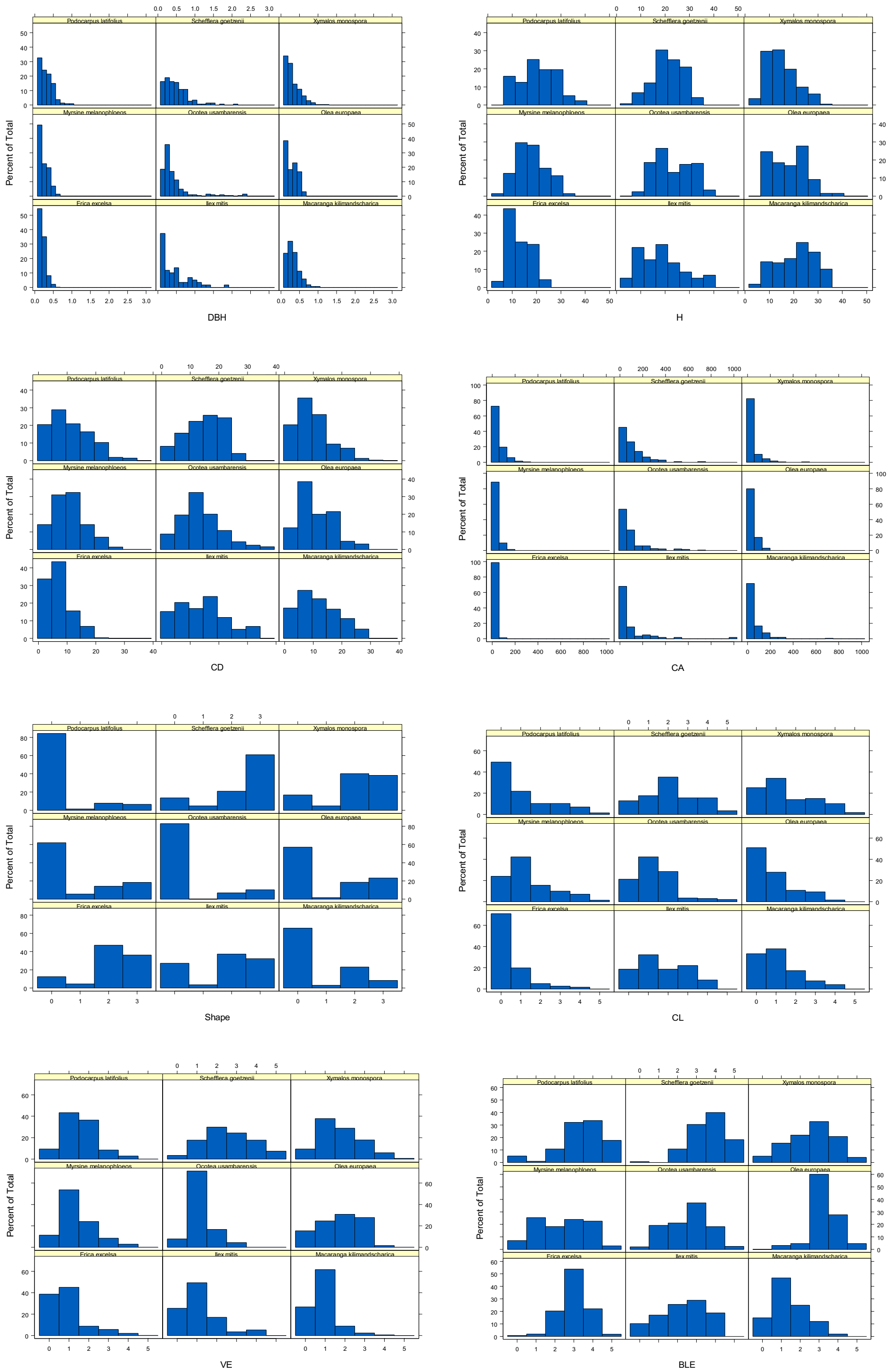

Fig. 6a-h. Relative distributions of characteristics of nine tree species, a. diameter, b. height, c. crown depth, d. crown area, e. trunk shape, f. climbers and vines, g. vascular epiphytes, h. bryophytes and lichens.

Table 1 The altitudinal gradient, main vegetation types and division in belts on Mt. Kilimanjaro from about 900 m a.s.l. through the agriculture areas below the forest and further through the forest to the forest border and above after Hemp (2006a). The distribution of the analyzed sites in this article along the three transects called Mweka (T1/P1-P18), Kilema (T2/P1-P20) and Marangu (T3/P1-P16) is shown.

Division after Hemp (2006a)				**Transects and sites in this investigation**		
Altitude m a.s.l.	**Main vegetation**	**Vegetation belts**		**Mweka T1/P1-18**	**Kilema T2/P1-20**	**Marangu T3/P1-16**
4000 - 3700	Remnants of *Erica trimera* forests	Subalpine				
(3500) 3200 - 2800	Pure *Erica excelsa* forest replacing *Hagenia* forest		Upper	P18		
3200 - 2800	*Hagenia-Podocarpus* forest with *Podocarpus latifolius*, *Hagenia abyssinica* and *Prunus africana*		Upper			
2800 - 2500	*Podocarpus* - *Ocetea* forest with prevailing *Podocarpus latifolius*		Upper	P17, P16, P15, P14, (P13)	P20, P19	P16, P15, P14, P13
2500 - 2200	*Ocotea* – *Podocarpus* forest, consisting of *Ocotea usambarensis* associated with *Podocarpus latifolius* and the tree fern *Cyathea manniana*	Montane	Middle	(P13), P12, P11, P10	P18, P17, P16	P12, P11, P10, P9, P8, P7
2200 - 1800	*Ocotea* – *Agauria* forest, *Ocotea* – *Syzygium* forest consisting of *Ocotea usambarensis* associated with *Agauria salicifolia*, *Syzygium guineense*, *Macaranga kilimandscharica* and *Polyscias fulva*		Lower	P9, P8, P7, P6	P15, P14, P13, P12, P11, P10, P9, P8, P7, P6, P5, P4, P3	P6, P5, P4, P3, P2, P1
1800 - 1500	Remnants of gorge and riverine forest in deep valleys with *Ekebergia capensis*, *Strombosia scheffleri*, and *Leptonychia usambarensis*		Lower	P5, P4, P3, P2, P1	P2, P1	
1500 - 1100	Riverine forests with *Mitragyna rubrostipulata* and *Newtonia buchananii*	Sub-montane				
1100 - 900	Savanna forest with *Acaia, Grewia, Combretum*; riverine forets with *Ficus vallis-choudae* and *Lecaniodiscus fraxinifolius*	Colline	Lower			

Table 2. Physical characteristics of the three transects on the southern slope of Mt. Kilimanjaro. Altitude measured with Thommen barometric altimeter (reference altitude at Moshi Clock tower 800 m a.s.l., the altitude at Marangu gate measured to 1810 m a.s.l., however, the sign at the gate states that the altitude is 1970 m a.s.l. For Kilema transect the sites in the lower part are situated 100 m from each other in order to give a more accurate description of the impacts from the populated area just below the forest reserve border to the HMFS. The exposition and slope are given in gon (400 gons equals 360 degrees).

	Transect		
	Mweka	Kilema	Marangu
Number of sites			
total	18	20	16
within HMFS	4	7	3
Altitude, m			
total	1270	890	800
mean altitude between sites	71	45	50
Elevation, m a.s.l.			
highest situated site (upper forest border),	2860	2670	2620
upper border of HMFS	1740	1880	2000
lowest situated site (close to reserve border).	1590	1780	1820
Exposition (^{g}),(gon)			
Average	205	180	200
Maximum	260	200	200
Minimum	140	150	140
Slope (^{g}),(gon)			
average	11	9	11
maximum	20	35	40
minimum	3	2	2

Table 3. The forty-nine species found as tree individuals in three transects and 54 sites on the southern slope of Mt Kilimanjaro, 1998 - 2003. Names and authors are after Lovett *et al.* (2006), Beetnje (1994), and Palgrave and Palgrave (2002). Ecology and distribution mainly after Lovett *el al.* (2006).

Family	Species	Ecology	Distribution
Pteridophyta			
Cyatheaceae	*Cyathea manniana* Hook.		
Spermatophyta	**Gymnospermae**		
Podocarpaceae	*Podocarpus latifolius* (Thunb.) R. Br. ex Mirb.	Montane-upper montane	Eastern, southern, west-central Africa
	Angiospermae ***Dicotyledonae***		
Apocynaceae	*Tabernaemontana pachysiphon* Stapf		Widespread in tropical Africa
	Tabernaemontana stapfiana Britten	Lowland, submontane-montane forests	Eastern, central Africa
Aquifoliaceae	*Ilex mitis* (L.) Radlk.	Montane, dry montane-upper montane forest	Tropical, southern Africa, Madagascar
Araliaceae	*Polyscias fulva* (Hiern) Harms	Montane forest	Tropical Africa
	Schefflera goetzenii Harms	Montane forest	Central, southern tropical Africa
	Schefflera myriantha (Baker) Drake	Montane-upper montane forest	Easter, central Africa, Madagascar
Boraginaceae	*Cordia africana* Lam.	Riverine, groundwater, dry montane, secondary forests	Widespread in Africa
Celastraceae	*Maytenus acuminata* (L. f.) Loes.	(Upper) montane, dry montane	Eastern, east central, southern Africa
Clusiaceae	*Hypericum revolutum* Vahl.	Often a pioneer, high altitude, open grass-lands, open forests	South Africa
Cornaceae	*Cornus volkensii* Harms	Montane forests	East central, eastern, south-eastern tropical Africa
Ericaceae	*Agarista salicifolia* (Comm. ex Lam.) G. Don	Montane, upper montane, dry montane forests	Eastern, southern Africa
	Erica excelsa (Alm & T.C.E. Fr.) Beentje	Upper montane forest, upland heath	Eastern arc, northern Tanzania, Kenya-Uganda
Euphorbiaceae	*Macaranga capensis* (Baill.) Benth. ex Sim var. *kilimandscharica* (Pax) Friis & M.G. Gilbert	Montane, upper montane forest, pioneer	Central, eastern tropical Africa

	Erythrococca bongensis Pax		
Flacourtiaceae	*Aphloia theiformis* (Vahl) Benn.	Upper montane, dry montane forest	Eastern, southern Africa, Madagascar
	Casearia battiscombei R.E. Fr.	Montane, upper montane forest	Eastern tropical Africa
	Kiggelaria africana L.	Upper montane, dry montane forest	Eastern, southern Africa
Guttiferae	*Garcinia volkensii* Engl.	Submontane, montane, upper montane forest	Eastern, central tropical Africa
Lauraceae	*Ocotea usambarensis* Engl.	Submontane, montane, upper montane forest	Central, eastern tropical Africa
Leguminaceae Mimosoideae	*Albizia gummifera* (J.F. Gmel.) C.A. Sm.	Riverine, dry lowland, montane, dry montane forest	Tropical Africa, Madagascar
Loganiaceae	*Nuxia congesta* R. Br. ex Fresen.	Upper montane, dry montane forest	Tropical southern Africa
Meliaceae	*Lepidiotrichilia volkensii* (Gürke) J.-F. Leroy	Montane forest	Central, eastern Africa
Melianthaceae	*Bersama abyssinica* Fresen.	Lowland, submontane, montane, upper montane forests	
Monimiaceae	*Xymalos monospora* (Harv.) Warb.	Submontane, montane, upper montane forest	Eastern, southern, Cameroons highlands, Equatorial Guinea
Myricaceae	*Myrica humilis* Cham. & Schltdl.		
Myrsinaceae	*Maesa lanceolata* Forssk.	Montane, upper montane, dry montane forests, forest edge	Tropical, southern Africa, Madagascar, Arabian peninsula
	Myrsine melanophloeos (L.) R. Br.	Occasionally dry lowland, usually montane, upper montane, dry montane forest	Tropical, southern Africa, Madagascar
Myrtaceae	*Eucalyptus saligna* Sm. (=? *E. grandis* W. Hill ex Maiden)	Exotic (from Australia)	Planted
	Syzygium guineense (Willd.) DC. subsp. *afromontanum* F. White	Submontane, montane, upper montane, dry montane, riverine forest	Eastern, central, southern tropical Africa
Oleaceae	*Olea europaea* L. subsp. *cuspidata* (Wall. ex G. Don) Cif.	Dry montane forest	Widespread in eastern, southern Africa, Mascarenes, Arabian peninsula to Iran, India, China
Pittosporaceae	*Pittosporum goetzei* Engl.	Upper montane forest	Eastern arc ?
	Pittosporum viridiflorum Sims	Submontane, montane, upper, dry montane forest	Tropical, southern Africa, Madagascar, southern India

Rosaceae	*Hagenia abyssinica* J.F. Gmel.	Dry montane forest	Central, eastern Africa, Zambia, Malawi
	Prunus africana (Hook. f.) Kalkman	Montane, upper montane, dry montane forest	Tropical, southern Africa, Madagascar
Rubiaceae	*Chassalia parvifolia* K. Schum.		
	Galiniera saxifraga (Hochst.) Bridson	Montane forest	Eastern, central, southern tropical Africa
	Keetia gueinzii (Sond.) Bridson		
	Lasianthus kilimandscharicus K. Schum.	Evergreen forest, forested ravines, riverine fringes	
	Psychotria cyathicalyx E.M.A. Petit	Montane, upper montane forest	Eastern arc (Us., S.Pare, Ul., Udg.,) northern Tanzania
	Psychotria fractinervata E.M.A. Petit		
	Psychotria sp		
	Tarenna graveolens (S. Moore) Bremek.		
Rutaceae	*Clausena anisata* (Willd.) Hook. f. ex. Benth.	Evergreen forest, low alt., along streams	Tropical, southern Africa, Comoros islands
Sapindaceae	*Allophylus africanus* P. Beauv.	Riverine forest, woodland, thicket, grassland	Widespread in Africa
Sterculiaceae	*Dombeya torrida* (J.F. Gmel.) Bamps	Secondary lowland forest, woodland, thicket	Eastern, central Africa
Thymelaeaceae	*Peddiea fischeri* Engl.	Submontane, montane, dry montane forest, forest edge	Tropical Africa
	Monocotyledonae		
Dracaenaceae	*Dracaena mannii* Baker (= *D. usambarensis* Engl.)	Lowland, submontane, montane forest	Tropical Africa

Table. 4. Structural characteristics of forest sites along three transects, Mweka, Kilema and Marangu on Mt. Kilimanjaro. Each site was 50 m x 20 m in size. With crown cover (%) means projection of crown cover irrespective of over-coverage, sum of tree crowns is a summation of the individual tree canopy projection. Density is number of stems. Basal area is based on DBH measurements at 1.3 m above ground. If not possible to measure at this height the DBH was estimated from measurements at other heights. Tree heights and crown depths were estimated. Sites above dotted line in each transect are within the Half-mile forestry strip (HMFS).

	Site no	Crown cover %	Sum tree crowns m^2	No of tree species	Density ha^{-1}	Basal area $m^2\ ha^{-1}$	DBH cm		Tree height m		Crown depth m	
							High-est	Mean	High-est	Mean	High-est	Mean
Mweka	1	20	820	6	220	12.1	49.0	24.1	19	12.8	16	8.3
	2	80	1400	6	190	32.5	81.8	41.6	50	26.4	32	16.6
	3	80	1420	7	320	32.9	79.0	31.8	35	18.2	25	11.1
	4	70	2850	14	300	33.1	90.1	32.4	40	21.3	35	15.6
	5	75	4560	7	340	56.2	130.6	37.8	35	22.8	29	16.2
	6	75	3110	5	330	50.3	66.2	41.3	38	29.4	25	15.6
	7	60	2390	9	390	49.0	72.9	35.4	33	22.3	32	14.3
	8	60	3690	11	460	138.4	235.4	40.4	37	21.2	33	12.3
	9	80	4210	8	520	103.5	226.1	31.5	40	16.8	39	9.4
	10	55	1780	6	340	83.5	200.6	37.5	35	21	27	10.5
	11	60	2180	4	290	111.0	240.1	42.8	32	19.3	27	10.9
	12	65	2630	7	440	93.0	191.1	38.4	40	21.2	35	12.5
	13	70	2420	6	280	61.0	152.2	41.8	36	19.4	33	14.1
	14	30	1590	7	200	18.9	59.9	30.4	33	20	26	13.1
	15	70	2820	5	730	68.8	98.7	29.8	29	18.7	23	7.7
	16	60	2000	5	390	48.6	130.6	30.3	35	18.3	26	9.4
	17	80	2300	9	510	79.7	172.0	31.2	32	17.1	26	9.1
	18	40	1570	5	460	26.3	53.5	25.5	26	17.1	21	11.5
Kilema	1	10	70	3	70	9.4	101.9	27.7	23	9.6	21	6.7
	2	10	160	2	40	26.3	119.4	87.3	25	17.3	22	14.3
	3	10	180	3	30	7.1	77.7	50.5	30	14.3	26	10.7
	4	30	210	2	40	9.3	74.8	52.0	30	14.0	27	10.8
	5	40	400	6	120	18.6	86.0	37.6	30	14.6	22	10.4
	6	40	600	8	170	23.3	93.6	35.0	25	15.1	20	9.8
	7	50	380	8	230	58.1	124.2	48.1	25	13.2	21	8.1
	8	60	690	5	200	55.7	207.0	42.3	30	14.5	24	7.2
	9	70	1880	5	190	32.6	70.7	42.4	28	16.4	22	10.7
	10	70	1460	4	150	106.5	311.1	64.1	35	15.5	20	9.3
	11	60	2800	6	220	93.5	180.3	59.9	40	22.2	34	17.7
	12	60	1090	6	260	57.6	99.0	45.5	28	15.2	23	9.8
	13	70	5450	7	320	67.6	104.5	45.2	28	21.3	26	16.4
	14	70	2050	7	170	45.1	113.7	51.5	35	20.4	32	14.6
	15	80	3210	7	520	40.2	60.5	29.1	23	16.8	19	9.6
	16	70	3240	6	370	37.5	82.8	31.3	30	19.1	28	13.5
	17	70	3330	7	320	60.4	114.6	41.7	38	23.5	34	15.9
	18	70	1870	6	420	42.3	80.6	32.3	28	18.0	22	12.8
	19	80	2190	4	370	68.9	143.3	42.1	38	26.4	31	13.5
	20	70	2750	8	1080	54.7	94.3	22.3	23	16.2	21	9.2
Marangu	1	15	620	4	280	21.7	73.2	28.1	18	9.8	12	6.0
	2	70	2680	8	360	50.2	131.5	31.7	35	15.4	32	9.6
	3	80	1790	7	520	40.7	102.5	27.0	28	16.1	23	7.7
	4	60	2410	5	620	59.0	107.0	30.1	32	22.1	28	11.3
	5	90	3050	6	510	61.3	93.0	34.1	32	19.1	27	10.4
	6	60	1830	13	760	39.7	70.1	22.7	26	16.3	18	9.6
	7	90	2370	10	620	54.0	82.8	28.2	28	15.7	23	10.2
	8	70	1650	10	890	46.9	95.5	24.2	24	14.8	20	9.0
	9	90	2890	5	420	65.3	140.1	38.0	32	21.8	24	13.0
	10	70	2710	6	400	66.0	89.2	41.8	28	22.2	25	14.4
	11	75	2260	9	690	47.1	70.1	26.3	28	14.6	18	8.9
	12	80	2680	12	660	48.3	74.5	27.4	30	17.1	24	10.8
	13	30	970	4	1600	36.0	26.8	16.0	18	10.5	15	5.7
	14	70	1810	5	3250	72.2	27.1	16.0	15	10.1	9	4.9
	15	20	70	2	20	10.1	99.4	77.2	20	19.0	14	11.0
	16	50	970	7	240	50.4	122.6	47.8	25	14.7	19	9.0

Table. 5. Correlations between stand characteristics in the sites situated in the forests. Correlation coefficient in the upper right part, significant correlations in italics ($p < 0.05$) or in bold ($p < 0.01$), N = 40, Spearman's rank test.

	1	2	3	4	5	6	7	8	9
1. Altitude	-	-0.112	-0.151	0.241	-0.131	-0.237	-0.262	*-0.315*	-0.240
2. Number of species	0.490	-	-0.046	**0.508**	0.249	0.261	0.173	0.018	-0.068
3. Basal area	0.351	0.776	-	0.002	0.211	*0.354*	*0.372*	**0.525**	0.271
4. Density	0.145	**0.001**	0.991	-	*0.394*	*0.325*	-0.093	-0.262	-0.200
5. Crown cover	0.420	0.122	0.191	*0.015*	-	**0.554**	0.144	0.149	0.080
6. Sum of ind. crowns	0.152	0.113	*0.029*	*0.046*	**0.000**	-	**0.499**	*0.355*	**0.516**
7. Crown depth	0.107	0.291	*0.020*	0.583	0-380	**0.002**	-	**0.802**	**0.679**
8. Highest tree height	*0.048*	0.913	**0.001**	0.112	0.359	*0.029*	**0.000**	-	**0.661**
9. Mean tree height	0.136	0.675	0.091	0.230	0.626	**0.001**	**0.000**	**0.000**	-

Appendix 1. Altitude and coordinates for sites along the three transects Mweka (1-1 to 1-18), Kilema (2-1 to 2-20) and Marangu (3-1 to 3-16) from the lower to the upper forest border on the southern slopes of Mt. Kilimanjaro. Altitudes are recorded by Thommen Barometric altimeter with Hotel Buffalo (Moshi) 820 m a.s.l. and Clock Tower (Moshi) 800 m a.s.l. as reference altitudes. Positions are mean value of several measurements recorded by GPS. UTM, coordinates 37MCG or 37M0396 (m). Datum: Arc 1960.

Site	Mweka			Kilema			Marangu		
no	Altitude m a.s.l.	03-	96-	Altitude m a.s.l.	03-	96-	Altitude m a.s.l.	03-	96-
1	1590	15590	44280	1780	30110	40990	1820	35160	42000
2	1610	15640	44340	1790	30140	41160	1860	35320	43290
3	1660	15520	44860	1810	30170	41300	1940	35340	43550
4	1710	15600	45100	1830	30120	41490	2020	35400	44000
5	1740	15730	45350	1840	30100	41590	2100	35450	44580
6	1810	16310	45720	1850	30070	41680	2160	35600	45290
7	1870	16440	45900	1870	29990	41810	2240	35530	46070
8	1910	16400	45990	1880	29950	42020	2280	35350	46390
9	2150	17100	46000	1890	29990	42140	2330	35020	46480
10	2265	17990	48030	1910	29950	42250	2390	34850	46900
11	2320	17310	48230	1930	29910	42410	2410	34950	47180
12	2450	17490	48580	1980	29890	42690	2450	34990	47430
13	2500	17480	48840	2020	29740	43030	2540	34750	48150
14	2530	17650	48900	2050	29700	43180	2580	34780	48430
15	2600	17630	49380	2110	28000	43200	2610	34850	48670
16	2670	17560	49720	2300	27610	44750	2620	34970	48700
17	2740	17820	50180	2430	27330	45810			
18	2860	18280	50720	2450	27390	45870			
19				2580	26990	47030			
20				2670	26620	47630			

Transect 1 – Mweka transect. The transect started at the Forest Reserve border at Kilema Nursery and National Park Ward, Mweka Corridor and proceeded along the Mweka corridor track, west of Charrango river.

Transect 2 – Kilema transect. The transect started at Forest Reserve border on the ridge between Ona and Mziri river in Kilema North Ward (Rua village) and followed the track. 14 sites were analysed between 1780 m to 2050 m a.s.l. Additionally six sites were analysed along the road passing the Old Sawmill above Kilema North Ward (west of Mziri river). These sites were situated between 2110 m and 2670 m a.s.l.

Transect 3 – Marangu transect. The transect started just after the large Eucalyptus stand at the Marangu Park Gate and proceeded along the rescue road and track to Mandara Hut. The 2 uppermost sites are along the track east of Mandara Hut.

Appendix 2. Reference points for determining the positions of sites on the southern slope of Kilimanjaro. Both GPS and altitudes are mean value of several measurements. GPS: UTM, coordinates 37MCG or 37M0396 (m). Datum: Arc 1960. Altitudes were recorded with Thommen Barometric altimeter with Hotel Buffalo (Moshi) 820 m a.s.l. and Clock Tower (Moshi) 800 m a.s.l. as reference altitudes.

Reference points	Altitude m a.s.l.	03xxxxx	96yyyyy
Reference site Hotel Buffalo	820	15610	29280
Transect 1, Mweka gate	1590	15610	44270
Transect 1, “1/2 Mile Strip”	1740	15730	45340
Transect 1, “End of Road”	1910	16410	46000
Transect 1, Bridge 1	2230	17160	47840
Transect 1, Bridge 2	2590	17690	49350
Transect 1, Mweka Hut/camp 2		18450	51278
Transect 2, House close to Forest ward dwelling	1800	29120	40650
Transect 2, “1/2 Mile Strip”, transect 2	1880	29940	42010
Transect 2, Saw mill	2210	28280	43760
Transect 2, Upper Forest Border	2690	26510	47820
Transect 3, Marangu gate	1810	35230	41772
Transect 3, “1/2 Mile Strip”	xxxx	xxxxx	yyyyy
Transect 3, “End of Road”	2330	35010	46500
Transect 3, Mandara Hut	2590	34707	48512

Appendix 3. List of the 49 registered species, with identification number (Id), recorded in 54 sites along three transects, Marangu, Kilema and Marangu, on the southern slope of Mt. Kilimanjaro, with two different shortenings and number of recorded stems in all sites.

Id	Species	Short shortening	Shortening	Number of stems
11	Agarista salicifolia	As	Agar sal	20
21	Albizia gummifera	Ag	Albi gum	5
44	Allophylus africanus	Aa	Allo afr	6
15	Aphloia theiformis	At	Aphl the	28
24	Bersama abyssinica	Ba	Bers aby	18
16	Casearia battiscombei	Cb	Case bat	1
35	Chassalia parvifolia	Cp	Chas par	1
43	Clausena anisata	Cla	Clau ani	6
8	Cordia africana	Coa	Cord afr	1
10	Cornus volkensii	Cv	Corn vol	5
49	Cyathea manniana	Cm	Cyat man	27
46	Dombeya torrida	Dt	Domb tor	10
47	Dracaena mannii Baker	Dm	Drac man	23
12	Erica excelsa	Ee	Eric exc	602
13	Erythrococca bongensis	Eb	Eryt bon	1
48	Eucalyptus saligna	Es	Euca sal	1
36	Galiniera saxifraga	Gs	Gali sax	39
18	Garcinia volkensii	Gv	Garc vol	1
33	Hagenia abyssinica	Ha	Hage aby	34
19	Hypericum revolutum	Hr	Hype rev	30
4	Ilex mitis	Im	Ilex mit	59
37	Keetia gueinzii	Kg	Keet gue	1
17	Kiggelaria africana	Ka	Kigg afr	2
38	Lasianthus kilimandscharicus	Lk	Lasi kil	2
23	Lepidiotrichilia volkensii	Lv	Lepi vol	3
14	Macaranga capensis var kilimandscharica	Mc	Maca cap	169
27	Maesa lanceolata	Ml	Maes lan	3
9	Maytenus acuminata	Ma	Mayt acu	28
26	Myrica humilis	Mh	Myri hum	1
28	Myrsine melanophloeos	Mm	Myrs mel	71
22	Nuxia congesta	Nc	Nuxi con	10
20	Ocotea usambarensis	Ou	Ocot usa	204
30	Olea europaea subsp. cuspidata	Oe	Olea eur	65
45	Peddiea fischeri	Pef	Pedd fis	6
32	Pittosporum goetzei	Pg	Pitt goe	2
31	Pittosporum viridiflorum	Pv	Pitt vir	1
1	Podocarpus latifolius	Pl	Podo lat	215
5	Polyscias fulva	Pof	Poly ful	13
34	Prunus africana	Pa	Prun afr	16
39	Psychotria cyathicalyx	Pc	Psyc cya	7
40	Psychotria fractinervata	Psf	Psyc fra	1
41	Psychotria sp	Ps	Psyc sp	4
6	Schefflera goetzenii	Sg	Sche goe	148
7	Schefflera myriantha	Sm	Sche myr	24
29	Syzygium guineense	Sg	Syzy gui	16
2	Tabernaemontana pachysiphon	Tp	Tabe pac	29
3	Tabernaemontana stapfiana	Ts	Tabe sta	30
42	Tarenna graveolens	Tg	Tare gra	1
25	Xymalos monospora	Xm	Xyma mon	394

APPENDIX 2

Paper V

Forest Ecosystem Mediating Indicator. A pilot scheme from the forest reserve at Mt. Kilimanjaro, Tanzania

Forest Ecosystem Mediating Indicator
A pilot scheme from the forest reserve at Mt. Kilimanjaro, Tanzania

John Eilif Hermansen

Abstract

Communication of ecological and environmental knowledge, values and concerns by means of indicators and indices is now widely accepted and adopted as a part of environmental management systems, results-oriented politics and international reporting and benchmarking initiatives.

The departure for this paper is the assumption that there is increasing asymmetry in understanding and control of forest ecosystem resources and services between the local, indigenous people as weak actors on one side and the globalized regime of science, international organisations and business as strong actors on the other.

This paper presents ecological indicators based on a system of communication and mediation that is intended to provide more equity for local interests, and may support democratization and enlightenment. The indicator is supported by a methodology for development of a multi-purpose ecologically-oriented forest management performance indicator system that also includes stronger participation of local people in defining and mediating the value of tropical forests. With the intention of supporting an open and interactive management system, this aggregated and complex indicator, where individual judgements are necessary, can be denoted as a soft ecological indicator. The ingredients of the indicator are selected on presupposition and distinction between the local and the global interests.

Motivation for the construction of the indicator system emerged during a case study of the catchment forest reserve on the southern slopes of Mt. Kilimanjaro. By using data from plant ecological investigation of the forest, an ideal typological indicator (Catchment Forest Ecosystem Mediating Indicator) is evolved. In order to anchor the indicator in systems thinking, a construct referred to as the Balanced Ecosystem Mediation Framework (BEM-framework is proposed.

Key words: Ecological indicator, index, environmental indicator, proximity to target indicator, systems thinking, tropical mountain forest, ecological communication, ecological mediation, forest management, participatory forest management, participatory forestry, Kilimanjaro

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Glossary

Term	Definition
Appurtenance	A right, privilege or interest belonging to and passing with a principal stakeholder (or property)
Communication	The overall instrumental, technical and practical process of either mutual or one way directed interchange of physical and social relevant data, information or knowledge between parties
Constructs	"are specific types of concepts that exits at higher levels of abstraction and are invented for some special theoretical purpose. Generally, constructs are not directly tied to observations" (Davies 1996:26)
COP	Conference of the Parties
Data	Observed, registered or collected pieces of information
Epistemological	Used here as the scientific way of acquiring knowledge
Global	Here referring to globalized systems like science, UN-system, NGOs, international trade and culture, multinational business, industry and transportation etc
Globals	People, stakeholders and institutions relatively free from local resources, obligations and the duties to the daily life of community, and members of the globalized regimes of concern, politics, NGOs, business and science, with an acquiring of knowledge based on science (epistemological approach)
Indicator	The term indicator is used throughout this paper as a generic term for a key number of selected data or a constructed index which is used to illustrate a complex ecological phenomena or management area.
Information	Knowledge communicated or received concerning a particular fact or circumstances
Locals	People (and stakeholders) depending and bound to local ecosystem resources and control over resources, and with an understanding of their resources based on traditional experience and knowledge (ontological approach)
Knowledge	An organized body of information belonging to a certain context either acquired by experience or scientific work
m asl	Meters above sea level
Mediation	Here a process of kind, friendly and benevolent exchange of information and knowledge in order to better understand each other and agree upon a joint and collective consensus based on a fair and deliberate cooperation
Negotiation	Here a process based on arguments connected to specific position which the parties a priori want to protect, strengthen or support as much as possible through the process, while the parties are still interested in an agreement which they believe is better than no agreement.
Ontological	Used here as framework for acquiring knowledge about the life world based on experience from daily life and historical traditions
Universal	Here referring to concepts, knowledge and values that are shared by any culture, community or society.

1 Introduction

Communication of ecological and environmental knowledge, values and concerns by means of indicators and indices is now widely accepted and adopted as a part of environmental management systems, results-oriented politics and international reporting and benchmarking initiatives.

Application of an indicator system is a normative course of action supported by different professional perspectives and parochial interests, struggling for resource control and ownership, investigation of business opportunities, and political interests. Development and selection of indicator systems is a natural extension of questions of justice and equity, and should accordingly be conducted in an open, transparent and consensus-based process in the spirit of enlightenment and democratic traditions.

Resource management initiatives have moved from the sphere of the ideological and political righteousness to the sphere of stakeholder valuation and negotiation, where traditional rights are no longer obvious and setting values has been professionalized and de-personalized. Local people may strengthen their stakeholder position by converting some of their understanding of the forest into a negotiable ecological indicator.

The purpose of this paper is to elaborate on the asymmetrical relationship between local and indigenous people dependent on their traditional rights to tropical forest habitation and those global interests who would intervene in their traditional understanding and use of the forest resources. Forest dwellers and native forest service users in developing countries may expect a large gap between their life world and the global actors. This paper further suggests a methodology for devising a forest ecosystem indicator system intended to balance the asymmetry and re-allocate some of the knowledge power about the forest resources back to the local community.

A framework for mediating ecological indicators is evolved in the paper in order to keep the elements of global versus local interests, nature versus society and epistemology versus ontology together in one system. The construct is referred to as the *Balanced Ecosystem Mediation Framework* (BEM-framework)

This framework emerged during a case study of the catchment forest reserve at the southern slopes of Mt. Kilimanjaro. By using data gathered during a plant ecological investigation of the forest (Hermansen *et al.* 2008), an ideal typological indicator, the Catchment Forest Ecosystem Mediation Indicator, was constructed using the framework.

A basic premise of this paper is that it should be possible to establish a negotiated understanding of tropical forest resources conveyed by a knowledge system that supports or at least evens out some of the asymmetric influence and power of the globalized community vis-à-vis the local community regarding communication of forest values. The theoretical and methodological approach is in this respect a paradox in light of the goal to support reinforced indigenous control over the existential prerequisites and local life world. Many objections easily can be raised, for example how can a Norwegian academic speak on behalf of people when he is not a part of and even ignorant to their cultural and social traditions? This intricate question remains unanswered in this paper.

The paper begins with background discussion of forest management and indicators followed by a description of the Kilimanjaro case study from which the framework emerged. The framework is described and discussed in section 4 before closing the paper with some conclusions and directions for further research.

2 Background

2.1 Local control and issues in forest management

The deterioration of tropical forests is increasing (Millennium Ecosystem Assessment (MA) 2005a, b, FAO 2007, UNEP 2007). The need for new initiatives for sustainable forest management has been raised by many authors and institutions (Van Bueren and Blom 1996, Studley 2007). There is a serious concern about insufficient means and instruments for a possible future sustainable use, management and governance of biodiversity and ecosystem resources (Noss 1990, 1999, Newton and Kapos 2002). Especially indigenous and poor communities are vulnerable to failed governance because of their heavy reliance on local, natural resources for subsistence and income (Lawrence 2000, Vermeulen and Koziell 2002, WRI 2003, 2005). Indigenous people and communities are also on the defensive in order to protect and develop their historical rights, cultural heritage, ecosystem resources and land. UN Convention on Biodiversity (CBD) made a so called COP decision on the framework for monitoring including 22 headline indicators (UN CBD 200X, 2006). Seven new targets for biodiversity will be added to the Millennium Development Goals in order to cover genetic variety, quantity of different taxon, geographic distribution and social interaction processes (Ash 2007).

Studley (2007) states that virtually all aspects of diversity are in step decline due to the three interacting interdependent systems of indigenous knowledge, biodiversity and cultural diversity. All three are threatened with extinction. The list of threats includes rapid population growth, growth of international markets, westernised educational systems and mass media, environmental degradation, exogenous and imposed development processes, rapid modernisation, cultural homogenisation, lost language, globalisation, extreme environmentalism and eco-imperialism.

Vermeulen and Koziell (2002) give a review of biodiversity assessment and integration of global and local values including elaborating on the contrast

> *"between "global values" – the indirect values (environmental services) and non-use values (future options and intrinsic existence values) that accrue to all humanity – and "local values" held by the day-to-day managers of biological diversity, whose concerns often prioritise direct use of good that biodiversity provides. Assessments are based on values."* (Vermeulen and Koziell 2002: ii)

Studley (2007) suggests a vision for realising the aspirations of indigenous people to ensure the enhancement of biological and cultural diversity which includes an endogenous approach dependent on building the capacity of forest development staff in acculturation, cross-cultural bridging, forest concept mapping and information technologies.

Wieler (2007) advises decision-makers that the development and implementation of an environmental monitoring system and adequate policy targets for improved environmental performance are crucial. She recommends an impact strategy that includes *relationship management* at the core to identify who are the people positioned to have influence on the changes that need to be made (Creech *et al.* 2006).

A wide variety of environmental and ecological indicators have been generated for the purpose of reflecting trends and needs for realising policy targets and improved nature management (Smeets and Wetering 1999, NRC 2000, Niemeijer and de Groot 2006).

Especially in cases where many stakeholders and their interests pose a complex cultural and social relationship to the resources, the process to define targets for environmental improvement and performance can be difficult. The process involves negotiation and mediation between those involved. A tropical forest land where local people are directly dependent on forest resources is an example of such a case.

In order to increase the efficiency of environmental policy and management a strong focus on performance is necessary and therein formulation of performance indicators. The purpose of this paper is to present a deliberate and communication oriented multi-purpose forest resource indicator which may be more equitable and understandable across cultural and societal borders, and also meet the requirements for a "proximity to target" approach (Este *et al.* 2006)).

2.2 Locally rooted proximity-to-target catchment forest indicator

Usually ecological or environmental indicators are part of a linear and hierarchical management system which includes monitoring, reporting and decision making. Van Bueren and Blom (1996) suggest a structure starting with determining goals, outlining principles and criteria with guidelines for action, which are measured and verified by indicators before they are compared with established norms and discussed. The hierarchy of the management system consists of the input (an object, capacity or intention, e.g. management plan), the process (the management process) and the output (performance and results).

The hierarchical model is systematic, logical and effective, but it is open in order to include the mediation and negotiation perspective that could increase the local people's participation and influence in local management. The model could be developed further to be more systemic and include feedback thereby reducing the asymmetry between global and local interests.

To incorporate both a systematic and a systemic forest management model it follows that a new approach to the construction of indicators is needed. Van Bueren and Blom (1996) outline very well the demand for quality in the work of designing sustainable forest indicators and they warn about incorrectly formulated criteria for management standards and indicators. However, an indicator for a forest management system that aims to increase local participation and equality regarding influence and control over local resources also must be easy to understand and use. The work for sustainable forest management rests on the assumption that local people understand how to protect the forest ecosystem services better than a scientifically constructed indicator, which fails to incorporate the knowledge of local people.

Therefore, this paper proposes a model for ecological communication that enlarges the objectives and application of ecological indicators. The proposed indicator framework has purposes beyond measuring ecological status, impacts or performance. The indicator should also be a tool for reflexive learning and communication including mediation and negotiation between stakeholders on the global and local scale, which includes nature itself represented by the sciences of ecology (Latour 2004, Hermansen 2006, 2008b) as a stakeholder (Elkington 1998).

The proposed indicators are referred to as the *Ecosystem Mediating Indicator (EMI)* and the *Forest Ecosystem Mediating Indicator (FEMI)* when applied on forest ecosystem services. Further, as an illustration of its application to the catchment forest reserve at Mt. Kilimanjaro, a special case is suggested called the *Catchment Forest Ecosystem Mediating Indicator (CFEMI)*.

CFEMI is meant to be an equitable, and ecologically acceptable, instrument for building up a reservoir of transferable knowledge. CFEMI is designed for communication and management of forest ecosystem values where there is a need for a significantly better quality communication process between the local level and global level of interests and concern.

First, ecology is addressed as a necessary knowledge system in an epistemological context for understanding the relationship and integration of natural resources to a globally recognized system, and second, the indigenous knowledge system is addressed in order to strengthen local motivation, control and proper management of community depending on a sustainable use of the ecosystem resources in an ontological context. This will be discussed in detail in section 4.

To make a distinction between the local context and interests and the global context and interests, two stakeholder groups, *locals* and *globals,* are introduced. The denotation of the rather new and little used term globals is not explained in dictionaries. Baumann (1998: 17) and Strassberg (2003: 645) refer to globals as people who are relatively free from territorial constraints, obligation, and the duty to contribute to the daily life of a community. Locals are geographically bound and they may bear the consequences of globalization. Bird *et al.* (2003: 404) elaborate on the relationship between proximate locals and globals that may find it more difficult to work with each other because of issues of Trust. This paper attempts to enhance the understanding of locals and globals to include not only interests but also the context of the understanding of the forest ecosystem in order to make an ecosystem indicator which is ecologically founded and accepted (global perspective) and locally understood and equitable (local perspective).

The goal is to devise a methodology that can generate locally controlled, adjusted and developed performance indicators. The proposed indicator is a composite indicator and was constructed by measuring the structural characteristics of a tropical moist, mountain forest. Compared to state indicators, performance indicators are more suitable for monitoring, showing trends, assessing improvements, for decision making and reflexive learning. The challenge in this case is the design of a system where a performance indicator can work appropriately and be integrated with an indigenous knowledge system. Scientifically oriented assessments and validations as well as normatively oriented assessments and validations are integrated with local understanding of the forest as a source of necessary ecological goods and services to the local community. To increase the momentum of an indicator system it may be designed as a *proximity-to-target* performance indicator. The process of deciding the targets provides an opportunity for locals and globals to make reflections concerning targets, i.e. the ecological quality of the forest.

2.3 Case: Catchment Forest Reserve, Mt. Kilimanjaro, Tanzania

Mainland Tanzania has according to Blomley (2006) one of the most advanced community forestry jurisdictions in Africa, and Participatory Forest Management (PFM) has become the main strategy of the forest policy. He states that among the lessons learned is an increasing awareness of the importance of local forest users and managers and he espouses decentralized forest management schemes. The indicator system suggested in this paper is devised to support these efforts.

Results from an ecological study of the moist mountain forest plants at the southern slopes of Mt. Kilimanjaro are used as a case for the creation of the indicator (Hermansen *et al.* 2008).

The indicator is meant to be embedded in the social context of the governmental forest policy especially the Catchment Forest Project (CFP) (Hermansen *et al.* 1985, Katigula 1992, Kashenge 1995, Ministry of Natural Resources and Tourism, Forestry and Beekeeping Division 1998, 2001, 2006). Creation of the indicator embeds an interpretation of possible interests and use of local ecosystem resources by the Chagga people and community (Stahl 1964, Newmark 1991, Misana 1992, 2006, Akitanda 1994, 2002, Ngana 2001, 2002, Soini 2005, Bart *et al.* 2006, Tagseth 2006, 2008).

Previously, national forest policy was an integrated part of governmental forest politics, but during the last 20 years forest policy has been more and more oriented towards a stakeholder approach (Hermansen 2008a). Sjaastad *et al.* (2003) has reported and analysed the stakeholder values for the Catchment Forest Reserves in Tanzania including South Kilimanjaro Catchment Forest Reserve.

The Chagga people and community at the southern slopes of Kilimanjaro are included in this study as representatives for local stakeholders whose interests are then juxtaposed to the global interests. The interests of the Chagga people are presented here as an ideal typological position (space does not permit a serious and fair study of the relationship between the local community and ecosystem services). The indicators can be considered to be a measure of the interest conflicts between locals and globals, and also between ecology and people. The preparation and use of the indicator may then be a useful tool in a tool-box for the "*keepers of the forest*" (Studley 2007) promoting interaction between the indigenous knowledge system, biodiversity and cultural diversity.

3 Case: Construction of the Catchment Forest Ecosystem Mediating Indicator

The *Catchment Forest Ecosystem Mediating Indicator* (CFEMI) is pilot scheme developed on site as a specific ecological mediating indicator. CFEMI is based on experience from an ecological investigation of the plant life in a tropical moist forest at Mt. Kilimanjaro (Hermansen *et al.* 2008) and the conceptual outline of a *Forest Ecosystem Mediating Index* (FEMI) suggested and argued for in chapter 4.

3.1 Introduction

Many definitions of sustainable forest management exist and can be found in the ISO standard on Environmental Management – Vocabulary (ISO 14050:2002). Additional terms and definitions from Technical Report (IO/TR 14061) (ISO 1998) refer to the two following definitions. The first one, from International Tropical Timber Organization says that sustainable forest management is a:

> *"process of managing permanent forest land to achieve one of more clearly specified objectives of management with regard to the production of a continuous flow of desired forest product and services, without undue reduction of its inherent values and future productivity and without undue undesirable effects on the physical and social environment*" (ISO/IS 14050:2002).

A second definition launched by the Pan-European (Helsinki) Process states that sustainable forest management is the:

> "*stewardship and use of forest and forested land in a way and at a rate that maintains their biodiversity, productivity, regeneration capacity, vitality and their potential to fulfil, now and in future, relevant ecological, economic and social functions, at local, national and global levels and does not cause damage to other ecosystems"* (ISO/IS 14050:2002).

The terms environmental and ecological indicators are often used as synonyms or in an arbitrary manner. In this paper, the notion ecological indicator is regarded as a subset under environmental indicator and use of the term ecological indicator applies directly to the ecological processes (NRC 2000: 19, Niemeijer and de Groot 2008: 91).

CFEMI is a composed indicator showing how far a certain site in a specific forest deviates from norms or targets, in this case sites at different altitudes in the forest belt between 1600 and 2700 m asl on the southern slopes of Mt. Kilimanjaro, see Figure 1. The targets represent a specific defined and assumed, optimal ecological state. It is essential to point out that the purpose of CFEMI is not to be universal, but instead to be a measure for strengthening the local actors's role in defining their forest resources and sustainable forest management in the context of the catchment forest. This means that CFEMI may be regarded as a quasi-indicator (Andersen and Fagerhaug 2002), more concerned with the local and situational reality and thereby of limited value for general utilization and comparability for benchmarking with other areas.

The procedure applied for constructing the indicator includes definition of system, goals, objectives, identifying relevant ecological factors and variables, outlining methods for measurement and data collection, negotiating the construction of the index and calculation of indicators, deciding on norms and target values, and finally the presentation of the proximity-to-target performance indicator.

3.2 Management of the catchment forest

Forest reserves in Tanzania have for more than 100 years been under different forest and forestry administration and management regimes from the German colonial time to the prevailing Catchment Forestry Project (CFP) launched in 1977 and organizationally situated under the Forestry and Beekeeping Division of the Tanzanian Ministry of Natural Resources and Tourism (MNRT).

In 1941, under British colonial time, a buffer zone, *The Half Mile Forestry Strip* (HMFS), was established as a social forest zone under local management of the Chagga Council (Kivumbi and Newmark 1991). The management worked very well the first 20 years, but after independence in 1961 the management became more centralised and the zone itself came under heavy pressure, overexploitation and encroachment from local people partly due to population growth and partly due to ineffective management. Most of the approximately 800 meter broad buffer zone along the eastern and southern part of Mt. Kilimanjaro appears even today as a seriously damaged forest far from its natural state.

Initially, the CFP did not manage the forest reserve very well, and encroachment, deforestation and fragmentation of the catchment forests increased (Hermansen *et al.* 1985, 2002, Newmark 1991, Katigula 1992, Lovett and Pocs 1992, Akitanda 1994, 2002, Kashenge 1995, Mariki 2000, Sjaastad *et al.* 2003, William 2003, Hermansen 2008a). Lambrechts *et al.* (2002) has verified the status and the extent of encroachment of the forest by aerial survey.

New national forest polices over the last 15 years have as a goal to improve the effectiveness and promote local responsibility towards a sustainable forest management practise (MNRT 1998, 2001, 2006) with the development of criteria and indicators for sustainable forest management in Tanzania (MNRT 1999). Local participatory forestry (Blomley 2006), forest management and democracy are all important issues and it not easy to find ways to transfer enough power and security to local communities and devise sustainable and effective local forest management (Wily 2001). Global initiatives connected to fair trade strongly support the strengthening of local forest management (Macqueen 2006).

The objectives of the CFP can be summarized to promote the utilization of the forest resources in a sustainable manner, and secure that the three key functions - production of forest goods, water generation and conservation of biodiversity of the forest - are maintained. The following interpretation of objectives forms the relationship between management purposes and ecological contents (Hermansen *et al*. 1985):

> ***Water generation****. Regulation and conservation of water resources and supply in the catchment area; reduction of run off and soil erosion, which is especially important in moist mountain areas.*
>
> ***Gene-pool conservation.*** *Preventing extinction of rare and endemic plant and animal species in the diverse moist forest; it is essential to maintain biodiversity and keep the genetic potential for ecological and evolutionary purposes and for present and future utilisation of biological forest resources*
>
> ***Production.*** *Logging of indigenous tree species and supply of other forest products for local consumption and sale.*

A number of recent studies describe, explain and discuss the forest ecosystem at Mt. Kilimanjaro, and the threats to and use of forest resources (Bjørndalen 1991, 1992, Misana 1992, 2006, Howell 1994, Hemp 1999, 2001, 2002, 2005, 2006a, b, c, Hemp and Beck 2001, Ngana 2001, 2002, Lyaruu 2002, Misana *et al.* 2003*,* Madoffe *et al.* 2005, 2006, Soini 2005, Bart *et al.* 2006). The arguments for understanding and supporting the conservation of plant biodiversity of the forest at Kilimanjaro are presented in many of the reference above, as well as many other articles, not referenced in this paper. Burgess *et al*. (2007) analyse the biological importance of Eastern Arc Mountains.

Some studies from Kilimanjaro and the neighbouring mountain forests (eastern arc) have included inventories suitable for supporting monitoring of the forests ecosystem services and contain data which are suitable to some degree for performance indicator systems, but they are mainly composed of distribution of tree species, density of trees and timber volume including regeneration (Jakko Pöyry 1978, Hall 1991, Malimbwi *et al.* 2001, Huang *et al.* 2003, Madoffe *et al.* 2005, 2006).

Also, the water management of the Pangani river basin, which is a very important regional and national concern, is tightly connected to the management of the catchment forest at Mt. Kilimanjaro (Ngana 2001, 2002, Turpie *et al.* 2003, Røhr 2003). The river is feed from several tributaries from Kilimanjaro and other hills and mountains in the area and runs in a south-easterly direction below the area shown in Figure 1.

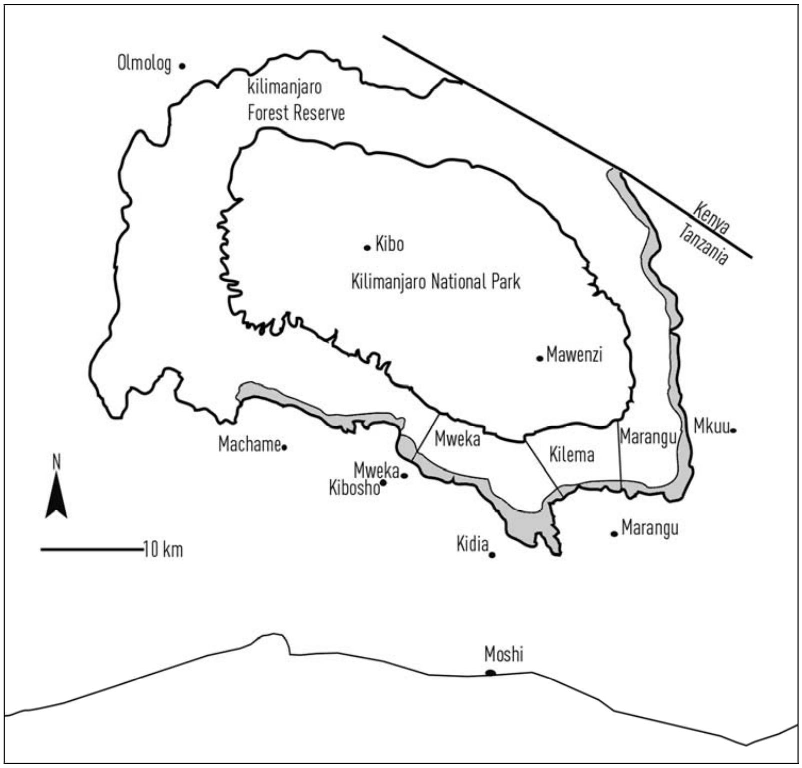

Figure 1. Kilimanjaro Forest Reserve and the three transects Mweka, Kilema and Marangu. The upper forest border mainly follows the Kilimanjaro National Park border. The Half Mile Forestry Strip is shaded. (Modified from Newmark 1991: 82)

3.3 Purpose and objectives of CFEMI

CFEMI offers a composite indicator of relevant ecological features that can be recognised as essential for catchment forest management; namely the conservation and protection of a specified forested area that serves local people with ecosystem services in a global perspective. Management means to keep and even enhance the forest quality within the area in order to improve water conservation and generation, to protect biodiversity and to serve local people with forest goods.

The overall goal of CFEMI is to contribute to a broad stakeholder-oriented approach (Grimble and Wellard 1997, Elkington 1998, Grimble 1998) to the knowledge and understanding of the forest and to promote an ecologically and socially wise use of the goods and services of the forest, including contributions to:

- reasonable common understanding of status and changes of the ecological conditions in the forest between globals and locals,
- motivating, learning and increasing a management oriented behaviour towards the forest resources,
- meet the requirement for local participation; application of the indicator could vary (e.g. full employment of the concept and indicator system or limited employment mainly showing the large structures in the forest).

Classes of objectives encompass:

- protection of forest ecology quality
- secure ecosystem services from the forest for the local people
- materiality for mediation and negotiation between locals and globals
- increasing local influence, control and competence regarding local resources
- provide opportunities for interactive learning loops.

The act of creating the indicator encourages mediation of the ecological aspects into a logical structure from goals to corresponding objectives, practical variables, measurement procedure and collection of relevant data.

3.4 Ecological and environmental aspects

This section will explore the variety of ecosystem assessment alternatives from the very general to the specific. Ecosystem assessment alternatives are provided from many sources. The first group of sources are various national forest policies including the CFP (Ministry of Natural Resources and Tourism 1998, 2001, 2006, Sjåstad *et al* 2003). The second group comprises strategies and efforts from international organisations. In addition to the authoritative bodies under the UN, such as FAO and others, the new initiatives connected to Millennium Ecosystem Assessment (MA 2005a, b) are most relevant. The third group is connected to the globalization of environmental management standards including sustainable forest management under the International Tropical Timber Organization. A fourth group is NGOs and research institutes working with tropical forest politics, management and forestry (Macqueen *et al.* 2006). Examples include the Forest Stewardship Council (FSC), Rainforest Alliance, Social Accountability International (SAI) and The International Social and Environmental Accreditation Labelling (ISEAL).

Macqueen *et al.* (2006) outline the new historical opportunities for community ownership and management of forest to realize a better position for sustainable forestry due to the alliance with a new kind of globals connected to initiatives such as fair trade and others. The World Business Council for Sustainable Development in alliance with IUCN has taken the initiative in recent years to meet the requirement and opportunities connected to Millennium Ecosystem Assessment (WBCSD and IUCN 2006). For CFEMI, the purpose and objectives of CFP are directly relevant, as are the linkages between E*cosystem Services and Human Well-being* of Millennium Ecosystem Assessment and the conceptual framework between biodiversity, ecosystem services, human well-being and drivers of change especially relevant.

Based on CFP and the MA framework, the ecological parameters for CFEMI can be grouped into two main categories a) forest structure and b) forest biodiversity. These categories have been chosen because maintaining these two qualities will secure that most of the other important ecological factors including microorganism and fauna and the abiotic environment, will be covered. If forest structure and biodiversity are intact on a certain level, the forest will keep its resilience potential and a number of other ecological qualities which can provide ecosystem services for human well-being in a sustainable way (Table 1).

Table 1. Overview of main ecological aspects, goals for management and ecosystem service of the catchment forest reserve at Mt. Kilimanjaro

Ecological aspect	**Management goals and ecosystem services**
Forest structure	Maintain a natural-like structure of trees including age/size (basal area and height of trees) and canopy cover and restore areas where the forest structure is damaged. Main ecosystem services: Constructs the forest room and constitutes the system for nutrient cycling, soil formation and primary production, form the overall habitat for all organisms, regulate local climate, retain, store and purify water and moisture and makes a optimal primary production possible Benefit for locals: Secure safe water for consumption and the furrow irrigation system produce timber, fuel wood, food, cash crops, fodder and many other bio products. Erosion control Income from tourism Benefit for globals: Timber, carbon storage, climate regulation. On regional level water to irrigation, hydropower, consumption and ecosystems via Pangani River basin water system is extremely import. Tourism especially eco-tourism
Biodiversity	Maintain natural level of biodiversity including diversity of trees. Main ecosystem services Provider of genetic material for large number of organism necessary for keeping the evolutionary potential intact, and provision of large number of different species Benefit for locals: Secure a wide variety of organisms to be utilized by the society where some already have known benefit for people and probably many other are undiscovered useful species which will be discovered in the future. Income from tourism

	Benefit for globals: Secure biodiversity resources for future generation. Medicines Ecosystem resilience Tourism and eco-tourism. Recreation

3.5 Selection of variables and primary indicators

The case of forest management at Mt. Kilimanjaro and the Chagga people as representative stakeholders for local interests is used here as an illustration of the conceptual and practical circumstances of the indicator scheme. CFEMI is proposed as a proximity-to-target indicator meant to work in the context of negotiation and mediation between globals and locals, while strengthening the local interests, influence, control and competence regarding sustainable forest management. The distinction between globals and locals are used to underline the actor perspective of the two paramount stakeholder groups of local society and international organisations, institutions and power structure. Both globals and locals are aggregates of other more specified stakeholders (See Sjaastad *et al.* 2003).

CFEMI should support the management goals for inter alia CFP and MA in a manner that strengthens the influence of local people and mediation between locals and globals. Table 2 gives an overview of criteria for selection of ecological features that could be relevant variables or primary indicators for CFEMI. Appendix 1 shows the complete list and description of the measured variables, units and levels of measurement.

Table 2. Criteria for the selection of variables

Criterion	Description
	ECOLOGICAL ASPECTS
1	Represent important forest physiognomy and biodiversity if trees on a plant are at an ecologically acceptable level
2	Directly associated to ecosystem services (Supporting, provisioning, regulating and cultural services)
	MEDIATION AND LEARNING ASPECTS
3	Easy or intuitively understandably by local people as a relevant description of forest services and goods
4	Support learning processes
5	Supporting learning processes and local participation in selection of indicators, measurement and calculation
6	Support management efforts
	TECHNICAL ASPECTS
7	Easy to measure and calculate
8	Does not hurt the ecosystem

Composition of variables is decided based on the criteria of what are relatively easily accessible. The variables cover important features for the ecosystem services connected to biodiversity and structure where the hypothesis is that the untouched forest has the potential to provide for the demanded ecosystem services such as production of forest goods (e.g. timber, fuel wood, fodder, medical plants), conservation of biodiversity, and water regulation and supply of water of good quality.

3.6 Measurement and data

More information about the ecological study including descriptions of the study area, field methods and discussion is presented in Hermansen *et al.* (2008). The detailed results are measurements taken of individual trees, both the measured variable and the aggregated data, for each of the 54 sites of 1000 sq. m along tree transects called Mweka, Kilema and Marangu. Once the variables were determined, data collection was based on rather simple methods and it should be possible for people with some experience in forestry and forest management to adapt the methods and use them. No advanced knowledge about species and taxonomy, or calculation methods was necessary.

3.7 Determination and calculation of targets

Identifying indicators, assessing possible values, and deciding on targets require both a quantitative and qualitative approach. Based on experience and criteria the target for each variable can be decided. A specific value connected to each target is calculated and partly estimated from average values from the cluster of sites. Table 3 gives an overview over objectives, ecological aspects and categories, indicator/variables, units, average score for all sites within each variables and target for CFEMI. Appendix 2 shows data for each variable and score as percent from target for each site (plot).

Table 3. CFEMI indicators and target values for ecological aspects.

Ecological aspects	Category	Indicators / variables	Units	Notes	Average	Target
Forest structure	**Tree structure**	Number of stems	no	1	40.6	50
		Basal area	m^2	2	6.0	7.5
		Tree height	m	3	19.2	24
	Leaf cover	Crown width	m^2	4	67.2	84
		Crown width sum	m^2	5	2416	3020
		Crown depth	m	6	11.8	14.7
Biodiversity and water conservation	**Epiphyte cover**	Covering of climbers	class	7	1.5	1.9
		Covering of vascular, lichens and bryophytes	class	7	2.3	2.9
Biodiversity	**Tree species**	Number of tree species	no	8	6.7	8.4

Data are based on the measurement and estimation of 1502 trees within 36 sites (plots) of 1000 m^2. The different targets are set close to the score for well developed stands and approximately 25 percent above average values. All the sites are within the forest reserve. Sites mainly containing more than 50 *Erica excelsa* trees and sites from Half Mile Forestry Strip are not included in calculation of average values and target values. Notes:

1. The number of trees per plot varies between 2 and 89. Overall average number of stems is 41.
2. The sum of basal area per plot varies between 0.1 and 13.2. The overall average is 6.0.
3. The tree height varies between 6 and 40 m. The overall average is 19.2 m.
4. The average crown width per plot (the horizontal project of the crown for each tree) varies between from 10 to 170 m^2. The overall average is 67 m^2. The largest crown is 961 m^2.
5. The sum of crown width for all the trees within a plot. The crowns are merged into each other and will therefore exceed 1000 m^2. The sum varies between 70 and 5450 m^2. The overall average is 2416 m^2
6. The crown depth varies between 7.2 and 16.2 m as average for the different plots. The overall average is 11.8 m. The highest tree crown depth is 39 m
7. Epiphyte cover is estimated by a non-linear classification and the calculated average is the average class for the tree within the plot. Target is set to 25 % above average. Average above 3.0 implies that the average tree has a substantial cover of epiphytes and climbers, which may play an important role for water conservation and retention.
8. The number of species within the plots varies between 2 and 13. The average is 6.7.

The reliability of data differs from variable to variable, and Hermansen *et al.* (2008) contains an outline of the inventory and a more complete discussion of the results. The most exact measures are identification of species, number of trees and basal area which is measured. Tree height, crown and epiphyte cover is estimated.

Calculation and display of results are made as easy as possible by allocating the same percentage value for each variable, and the results from the calculation will reveal which sites are far from the ideal typological state. The model shows both the factual relationship between the sites and a significant difference between them, which also will appear if we look into the data lists.

3.8 Results

The proximity-to-target score for the sites along the three altitudinal transects from lower to upper forest borders at the southern slopes of Mt. Kilimanjaro of Mweka, Kilema and Marangu, is shown in Appendix 2 and Figures 2, 3 and 4. Table 4 shows average values for the sites along each transect grouped into three zones: HMFS, central part and the upper part of the forest reserve.

Table 4. Average CFEMI score group for the three distinct altitudinal zones of the forest along the three transects Mweka, Kilema and Marangu at the southern slopes of Mt. Kilimanjaro. Number of sites is shown within parenthesis.

	Mweka		Kilema		Marangu		Average	
HMFS	68	(4)	50	(7)	72	(3)	60	(14)
Central part	101	(8)	96	(11)	101	(9)	99	(28)
Upper part	94	(6)	93	(2)	90	(4)	92	(12)
Average	91	(18)	80	(20)	93	(16)	87	(54)

14 of the 54 sites have score higher than 100 (see appendix 2).

The HMFS shows, as expected, much lower values (average score: 60) compared with average score 99 for the central part and 92 for the upper part. Average scores for the complete transects are quite similar for Mweka (91) and Marangu (93) and lower for Kilema (80). It is the low values from HMFS (50) along the Kilema transect which draws that average down. In the Kilema transect about double as many sites were measured in the HMFS part of the transect as in the two other transects. Sites on low altitudes are overexploited and well developed sites are situated on higher altitudes (Fig. 2, 3 and 4).

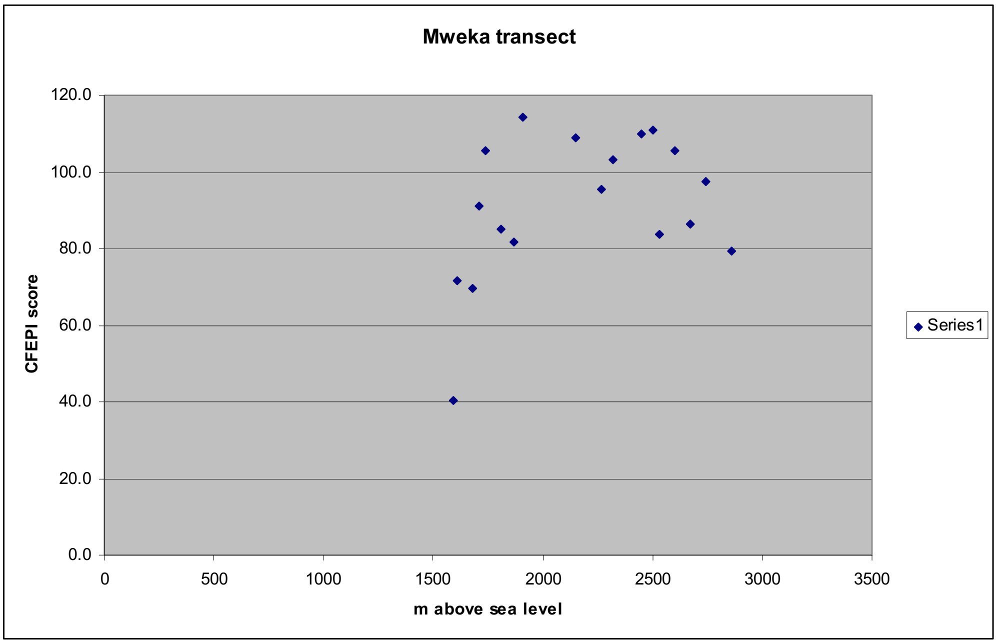

Figure 2. Proximity to target in percent for the sites along the altitudinal transect at Mweka. HMFS is between lower forest reserve border at 1590 and 1740 m asl and uppermost site at 2860 m (close to upper forest border)

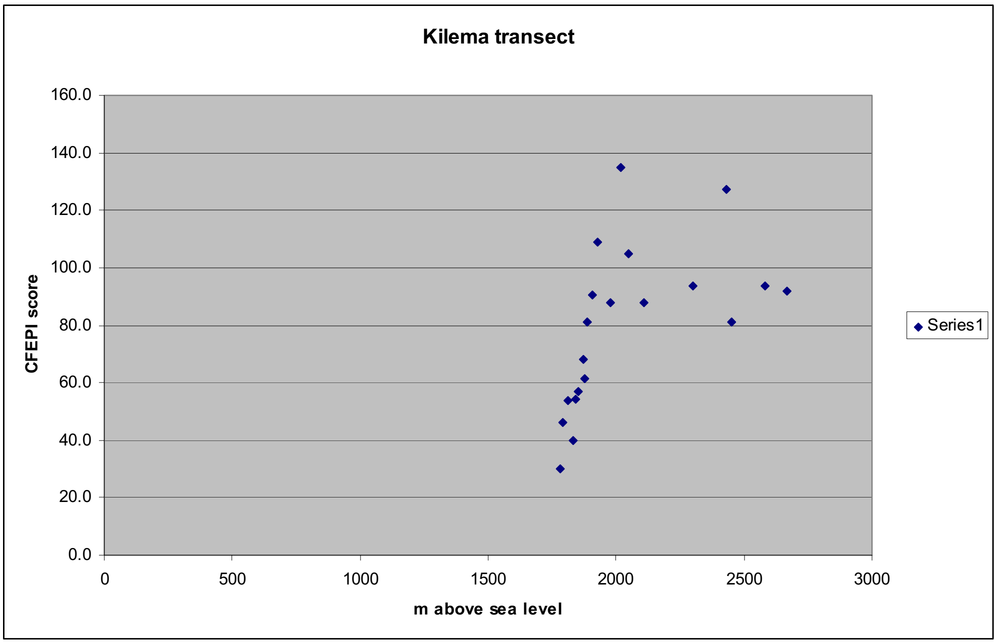

Figure 3. Proximity to target in percent for the sites along the altitudinal transect at Kilema. HMFS is between lower forest reserve border at 1780 and 1880 m asl and uppermost site at 2670 m (close to upper forest border)

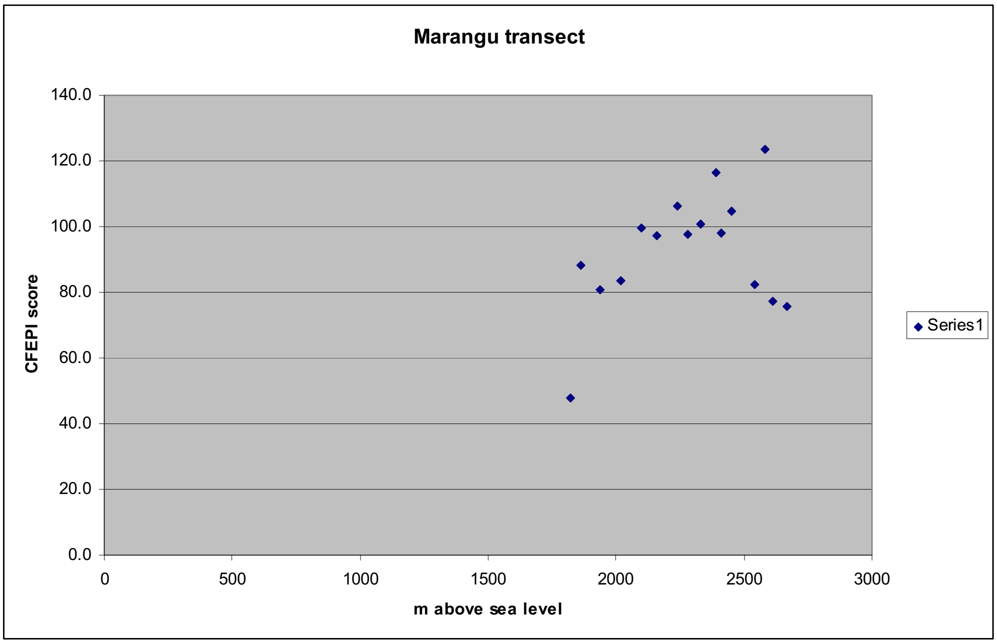

Figure 4. Proximity to target in percent for the sites along the altitudinal transect at Marangu. HMFS is between lower forest reserve border at 1820 m and 2000 m asl and uppermost site at 2620 m (close to upper forest border).

The most significant observation is the delta in the range of score on the Kilema track from the lowest (30 percent point) to the highest score (134 percent point). Especially the sites in the HMFS are far from the target for an ideal forest composition and structure. However, this was expected and obvious from simple visual inspection of the area. The HMFS is allocated to a buffer zone and people in the adjacent home garden farm land can collect fuel wood and other goods in strip under certain rules. But for all transects, the cutting of trees degrades the forest considerably. Some sites would not be categorized as forest according to standard definition. The total area of HMFS is 8769 ha where about half of this land can be afforested (Kivumbi and Newmark 1991) and where there is considerable potential for increasing the forest quality and hence the value of forest ecosystem services to the local people by better management.

For all transects, the most well-developed and maintained sites are between 2000 to 2500 m asl as noted by the fact that many of these sites scored above 100.

Based on these data, it is reasonable to conclude that the CFEMI represents the ecological quality of the different forest sites.

4. Framework for mediating balanced ecosystem indicators

4.1 Methodological approach

The methodology for development of FEMI/CFEMI is basically built on systems thinking and elements from systems engineering and used as tool for connecting different subsystems, such as stakeholder interests, forest ecology and management together into the larger system where FEMI is meant to work. An essential part of the EMI, FEMI and CFEMI methodology is the construction of the communication model Balanced Ecosystem Mediation (BEM) framework.

4.2 Systems approach and the construction of the BEM framework

The construction of the indicator is built on a pre-understanding of communication as an instrument for mediation and negotiation of knowledge and interests, and that these processes are integrated and accepted as fundamental for further development of the context where FEMI will contribute.

Technically, most environmental indicator systems are designed within an open system concept which includes conceptual, normative and operational elements. The notion of a system often encompasses "*a combination of interacting elements organised to achieve one or more stated purposes"* (Haskins 2006), and could be an assemblage of elements constituting a *natural system*, a *man-made system*, an *organizational system* or a *conceptual knowledge system* (Asbjørnsen 1992).

An ecological indicator system aiming to be a management tool can be defined within all these four classes of systems and merged into an overall communication system where the indicator and the different circumstances around the indicator become elements in the system. The challenge is to design and understand how the interaction across the boundary interfaces between the elements, the subsystem and eventually the environment outside the system boundary, influence and bring the system into being. Systems thinking is an underlying concept used to assist in combining the ecological and social elements in the development of FEMI such that the indicator moves closer to a management and stakeholder approach.

Van Bueren and Blom (1996) advanced the *"Hierarchical Framework for the Formulation of Sustainable Forest Management Standards. Principles, Criteria, Indicators"* (PCI) on behalf of Tropenbos Foundation which challenges many of the aspects relevant for the FEMI indicator system. They suggest top-down oriented hierarchal framework for a forest management system with consistent standards based on the formulation of principles, criteria and indicators for sustainable forest management (Figure 5). In the context of development of FEMI, the PCI system appears to be an expert-oriented initiative that belongs to the sphere of influence and interests of the globals.

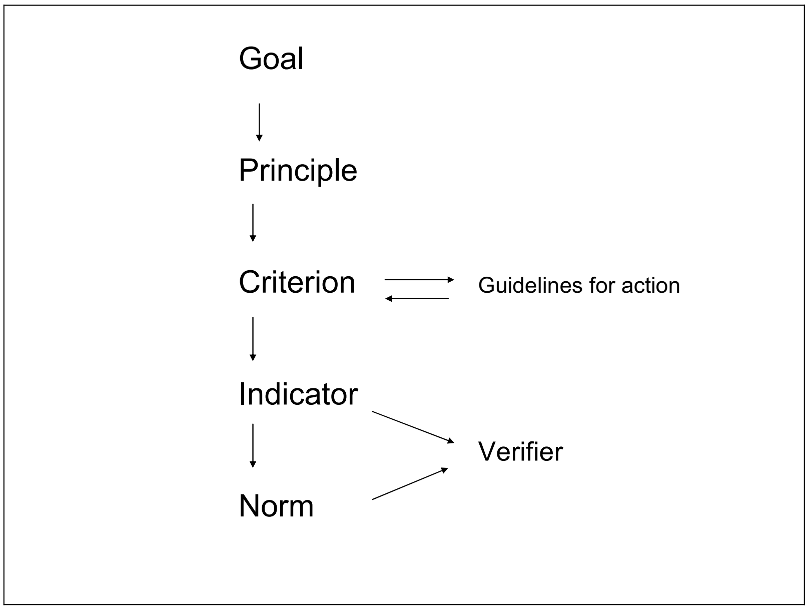

Figure 5. The linear hierarchical PCI framework for the formulation of sustainable forest management standards (after Bueren and Blom 1996: 15)

In order to create a structure involving the locals and strengthening their interests while supporting dialogue and continuous learning, the PCI framework has been modified. The proposed structure allocates the indicator system a more interactive role, and enlarges the system to a construct that shows an ideal typological symmetric mediation between the locals versus globals, ecology versus nature (resources or ecosystem services), and society versus culture Hermansen 2008b). The new framework is called the *Balanced Ecosystems Mediation (BEM)* Framework (Figure 6).

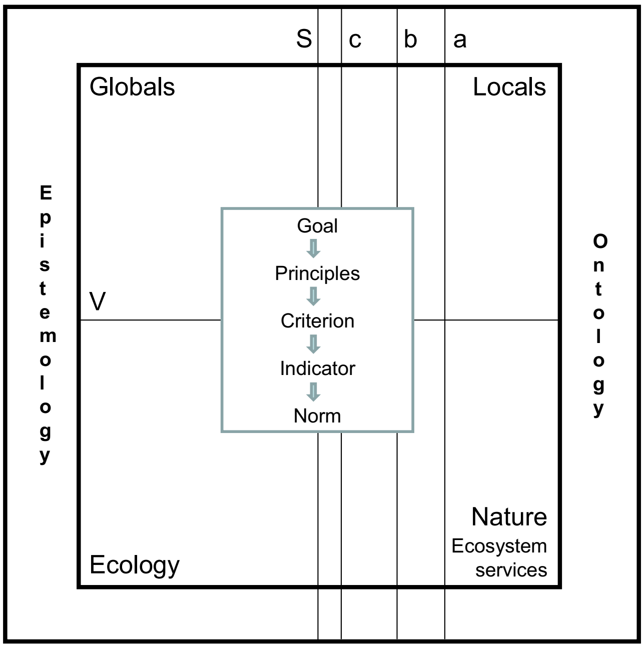

Figure 6. The construct of the Balanced Ecosystem Mediation (BEW) Framework with the two knowledge regimes ontological and epistemological. S and V are representing the ideal typological symmetry (or balance) regarding mediation and negotiation for globals versus locals stakeholders and society versus nature (as stakeholders) respectively. The indicator is here meant to be a Mediating Ecosystem Indicator (MDI).

The transecting lines S and V in Figure 3 represent the ideal symmetric or balanced case based on scientific and normative criteria and arguments. The vertical lines a, b, and c illustrate different constellations where the position, influence and control by the locals is more or less reduced or lost to the globals. The line **a** shows the situation where the locals are incapacitated and have lost most control over their ecosystem resources; line **b** represents the situation where the locals have managed to participate in forest management; and line **c**, the situation where the locals have substantial influence and control over local ecosystem services.

If *V* is moving upwards the ecological interests and concerns increase with stronger emphasis on protection and conservation, and if *V* is moving downwards, society takes more of the ecosystem services with an increased ecological unsustainability impact and possibly a strong attenuation of the ecological resilience capacity.

The BEM framework should be regarded as an open system where the borders between the elements and subsystem are interfaces where mediation and negotiation can occur between the stakeholders involved. Both mediation and negotiation can take many forms depending on the question discussed or stakeholders (and subgroup of stakeholders) participating in the discourse.

The corresponding influence of how the understanding of ecology (scientific) and nature, and the epistemological and ontological approach, are also illustrated in Figure 6, and derives from the case study work in which the *indicator* was designated to be the core element in the forest management system in order to strengthen the position of the locals. The BEM framework is built on a nature versus culture model presented in Hermansen (2006: 90), and further developed in Hermansen 2008b.

FEMI is the general and theoretical model for the indicator, while CFEMI is intended to be a specific and practical indicator reflecting the complexity of the relationship between the catchment forest ecosystem and local society.

4.3 Terms and theoretical perspectives of the communication model

The intended purpose of the development of a communication process can be illustrated as shown in Table 5.

Table 5. The context of knowledge regimes and appurtenance for globals and locals for the Forest Ecosystem Mediating Indicator (FEMI) concept.

	APPURTENANCE OF ECOLOGICAL KNOWLEDGE	
Knowledge acquisition	**The globals**	**The locals**
By experience /empirical	The ecological accepted (relevant)	The ontological regime
By scientific work/methodological	The epistemological regime	The social accepted (relevant)

The two knowledge regimes (empirical and methodological), which are two different ways of acquiring and constructing knowledge, are paired with the accepted viewpoints of both globals and locals about ecological issues. A normative standpoint is taken by insisting on the right of local people to understand and participate in a discursive reflection on the content and value of the indicator system. The appurtenance interests of the globals comprise the ecological area regarding empirical knowledge acquired by an epistemological methodological approach, and the appurtenance interests of the local comprise the ontological way of experience of nature and natural resources and later ecological knowledge acquired by scientific work.

4.4 Goal and objectives of forest ecosystem mediating indicators

Objectives and practical use of the indicator are intended not only to be a measure for communication, but also for mediation and negotiation process in itself and the further understanding of forest ecosystem and management of the forest resources. The indicators are part of the process and the overall objective can be specified by separate regimes and roles into the following regimes/roles as shown in Table 5. First the paramount objective must be stated and the context of mediation by means of indicators must be set.

Paramount goal
Contribute to democratized and enlightened mediation of ecosystem knowledge, services and values between nature and society, and strengthen the locals' position in the locals versus globals relationship

The ultimate goal is the wise and sustainable use of the forest. Table 6 shows the relationship between the main features of the ecological mediation.

Table 6. Paramount goal and mediation of ecology

Paramount objective	Democratized	Enlightened
Ecosystem knowledge	Mediation of scientific results	Mediation of scientific methods
Ecosystem services and values	Mediation of local resources	Mediation of scientific values/understanding

The integrated mediation by means of indicators is dynamic and process oriented interchange and can conveniently be divided into different phases (Table 7). These phases also give an indication of the learning cycle of the activity.

Table 7. Matrix of the objectives and tasks typology of the different interests and mediation phases

Mediation phases	Local interests and impact	Global interests and impact	Negotiated goals or aspects
Pre process understanding	Identify local concern and needs	Identify global concerns	Agree on concerns
Interpretation of positions	Identify local human resources	Identify scientific knowledge	Combining human resources
Designing phases	Defining need of ecological services: Water, fuel wood, timber etc	Defining biodiversity and climate issues	Defining a complete description of values and resilience capacity
Pre-inventory	Practical training	Communicating support	--------
Part of inventory	Identifying and deciding	Be accepted as partner	Agree on working methods
Part of management	Control	Protect global ecological concern	Agree on management system
Part of continuously learning and negotiation process	Full access as respected partner	Move from global arrogance to universal partnership	Common interests of using the communication opportunities of the FEMI construct

Mediation is not only an end-of-project activity, but an integral part of project development. Suitable settings for mediation can be established prior to inventory (as part of planning), part of field work (inventory), part of management and part of a continuing learning and negotiation process. In a dialogue, stakeholder's interests are also maintained, represented here by local and global interests with accompanying impacts. Negotiated goals and aspects are the result of the process, integrating the consensuses of ecological content, definition of ecological service and values, and suggesting a political/management ecological regime that embraces the negotiated knowledge regime. Through genuine communicative mediation an equitable and symmetric communication process may then emerge.

The objectives of the index are as follows:

- contribute to the indigenous knowledge system for the local forest ecosystem and enlarge the capacity and the position for acculturation and cross cultural bridging
- motivate the maintenance of ecosystem and ecosystem services
- communicate ecological information
- mediate the ecological values between indigenous people and multiple stakeholders.

- contribute to enlightenment
- contribute to democratizing of ecological resources management.

4.5 Using FEMI to bring momentum to local management

Millennium Ecosystem Assessment (MA 2005a) is an initiative for handling the ecosystem resources under the vision of a globalized world and offers a framework both regarding ecosystem and geographic scaling. It further elaborates the relationship between the ecosystem and the human needs for ecosystem services that contribute to well-being and poverty reduction in the form of security, basic material for a good life and good social relations. This in turn necessitates requirements for freedom and choice of action. Status and quality of the forest on the global and regional scale will often be assessed in coarse categories such as area cover by forest, degree of deforestation, estimates of economic value of logs, stakeholder values etc. Application of the MA concept can easily result in a change of resource control and management away from already weak local participants to international bodies and business. FEMI is meant to adjust the management attitude in MA to facilitate a stronger local participation.

Assessments of the ecological status and trends require a set of indicator systems. The Driving force – Pressure – State – Impact – Response (DPSIR) framework (Smeets and Wetering 1999) is often used. However, Niemeijer and de Groot (2008) argue that moving the framework for environmental indicators from causal chains to causal networks could be a better tool for management decisions and they suggest an enhanced DPSIR-system that could be appropriate. FEMI can be considered as a local status indicator, but with the concept of proximity-to-target as the principle design of construction, the indicator acts as a performance indicator where performance (status) is compared with a defined ideal typical well developed, natural and healthy forest (the target).

Hence, the intention of FEMI is to enlarge the framework for an ecological forest indicator to include ecological integration and the potential for a larger understanding and dynamic involvement among stakeholders.

4.5.1 Proximity-to-target performance indicator

To measure ecological and management oriented policy categories, such as for example the wise and sustainable use of forest resources, requires a set of different measurable indicators and data. Some are easily measurable with instruments and metrics, and others by judgement, often value laden along a scale. Performance indicators on social level usually refer to different kinds of reference conditions and values, such as national or international policy targets. Especially demanding, both technically and politically, is the implementation of sustainability performance indicators. Often they are very vague and difficult to follow up and address with responsible authorities or actors.

European Environmental Agency (2007) has defined the usefulness of a proximity-to-target approach:

> *"... concept of environmental performance evaluation is being developed for use in an environmental management system to quantify, understand and track the relevant environmental aspects of a system. The basic idea is to identify indicators (environmental, operational and management) which can be measured and tracked to facilitate continuous improvements. Performance indicators compare actual*

conditions with a specific set of reference conditions. They measure the 'distance(s)' between the current environmental situation and the desired situation (target): 'distance to target' assessment."
(EEA, Multilingual environmental glossary, internet)

Proximity-to-target indicators are a type of environmental performance indicator designed for ranking, benchmarking and monitoring action towards some well defined and measurable objectives. The proposed CFEMI is an extension of the concepts and principles from both the macro (societal) and micro (corporate) levels including mimicry of the proximate-to-target indicator from '*Pilot 2006 EPI Environmental Performance Index*' launched by Esty *et al.* (2006).

4.5.2 Reliability of measurements

To make high quality, representative measurements of forest variables, is a challenge. West (2004: 7ff) gives an account of *accuracy* as the difference between a measurement or estimate of something and its true values, *bias* as the difference between the average of a set of repeated measurements or estimates of something and its true value, and *precision* as the variation in a set of repeated measurements or estimates of something.

Because much of the measurement phase of the field work is dependent on assessment of the values for the different variables, the indicator is vulnerable to the skills and experience of the observers. Within a close collaborating group of local foresters the observations can be sufficiently accurate, but comparing the results between different forests and assessment teams, the assessment could vary significantly.

5 Discussion, conclusion and further work

5.1 Discussion

The scientific judgement on the feasibility of FEMI and CFEMI will depend on expectations, and many of the same demurs and critics discussed by Andreasen *et al.* (2001: 32) can be raised. Their concept for a terrestrial index of ecological integrity which incorporates information from the multiple dimensions of ecosystems is expected to be a useful tool for ecosystem managers and decision makers. FEMI and CFEMI, however, are devised both to expose ecological integrity, and to be instrumental for the mediation between nature and society, and between locals and globals. This implies that the ultimate results of the application of the indicator is connected to the process of continuing improvement of the genuine understanding between the globals and locals, and the continuing improvement of the management of the forest in order to secure the ecosystem services for the local people as first priority and for the globals as second.

Working out the indicator system and then executing the implementation both contribute to the momentum of the learning loops and to the factual learning about the very easy accessible features of the forest ecosystem and corresponding ecosystem services.

Both selection of ecological phenomena, variables, field methods and measurements, and composition and calculation of the composed indicator are critical issues. To achieve a sufficient accuracy is difficult for many of the variables especially those depending on estimation of heights and cover. The success of the indicator will depend on how the balance of purpose, accuracy and selection of possible variables are compared with the momentum for increased local participation, increased consciousness and ecological knowledge, and increased motivation for interactive cooperation for finding wise solutions.

Local participation of sustainable management of a tropical forest requires that the knowledge about ecological status and the ecosystem services that the forest can provide, can be communicated in way that support enlightenment, democratic management processes and are environmentally sound. Hence, whole process of development and implementation using ecological indicators should be scientifically and ecologically proper (the global perspective) and locally understandable and fair (the local perspective). The case study shows that it is possible to carry out field inventory programs that encompass variables that cover main ecosystem services especially valuable for local and regional utilization, by using simple measurable ecological variables.

However, many of the measured variables depend on estimations of measured values and the measurement could then be less reliable for calculation of the indicator.

The Balanced Ecosystem Mediation Framework serves as mental model for the communication process, and the validity of such a model can only be understood by an investigation among people and stakeholders involved.

It can be noted that the connection to the real conditions at the slopes at Mt. Kilimanjaro in this case is rather weak because the detailed investigation of the relationship between society and ecosystems is not done or taken into account. Assessing and making decisions about ecosystem resources is a normative and political action, and a challenge for an indicator system is then to make the normative dimension visible and an object for deliberative processes. To meet the requirement for local participation the indicator system has to move from a hard ecological approach with only measurable indicators to a practical and soft ecological approach and use an open, conceptual and learning oriented systems engineering approach. This movement from a hard system towards a soft system allows greater application of assessment, judgement and estimation as discussed by Mendoza *et al.* (2006).

5.2 Conclusion

This paper has demonstrated the use of ecological indicators to support a balanced and theoretical approach to increasing the influence of local interests on vital forest resources, and to encourage knowledge insertion to achieve a proactive approach to sustainable management.

The case shows that the indicator can provide easy accessible information about essential ecological features about the different sites, which then can be compared and monitored.

Until the BEM framework or similar constructs have been studied, they will probably mainly instrumental to the meta-discussion on the relationship between stakeholders (globals versus locals and society versus nature).

Judging the results of a mediating ecological indicator system will depend on testing the relevance and expediency of the indicator on integrated and participatory forestry projects. However, it is still reasonable to expect from the experience of the field work reported here and from literature about local forest management and use of ecosystem services, that the implementation of an indicator based on the suggested methodology and measure for increased local involvement, could work.

5.3 Further work

There is a need for further investigation along the following three directions in order to increase the validity of the ecological indicator system as an appropriate tool for resolving the asymmetry between the local and global interests in forest management:

- increase the knowledge of how such a system is perceived by locals and how they can be rooted and applied in local forest management
- mature the indicator model and the selection of variables further in order to better cover the forest ecosystem services, but still remain a simple and useful tool for design, implementation and operation of the system
- explore how to develop and connect such initiatives deeper into a learning process and as a genuine measure for mediation, negotiation and decision making.

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Appendix 1
Measured and analyzed variables

Tree structure variables		Description	Units	Symbol
A. Basic units		Inventory units for identification, geo-referenced information and multivariate analysis		
a.	Tree	Individual identified and measured tree or stem		
		o Running serial number		Idnr
		o Running serial number within plot		No
b.	Plot	Identified by transect and plot number		
		o Mweka transect		T1Px
		o Kilema transect		T2Px
		o Marangu transect		T3Px
B. Localization				
a.	Altitude	Altitude above sea level	m	m asl
b.	Transect	Transect from lower to upper forest border	Nominal	T1, T2, T3
c.	Exposition	Indication of exposition in 400 grades	degrees	
d.	Slope	Indication of slopes in 400 grades	degrees	
C. Stem				
a.	Tree number	Each tree (or stem on trees divided in 2 or several stems under 1 m) is identified by transect and running number with the plot	Ratio	No
b.	Tree species	Each tree is identified		
c.	Height	Estimated height	m	H
d.	DBH	Measured diameter at breast height	m	DBH
e.	Basal area	Calculated basal area	Sq. m	BA
f.	First branch	Height to first leaving branch	m	FB
g.	Shape	The shape of the trunk is assessed :	Nominal	
		o Straight		0
		o Leaning		1
		o Bent		2
		o Crooked		3
h.	Buttress	Each tree has been assessed if it has buttress or no	Yes or no	Y, N
D. Canopy				
	Crown area (total leaf area)	Estimation of the horizontal projection of the canopy of each tree. The area is calculated from estimation of the diameter of the crown along to axis through origo.	Sq. m	CA
E. Epiphytes:				
a.	Climbers	Estimation of the cover of climbers and lianas on each tree:	Nominal	
		No climbers or lianas observed		0
		Some few / thin climbers, shorter than 2 m		1
		Some more dense / thicker climbers, more 2 m long		2
		Climbers cover the stem and some thin lianas may occur.		3
		Large and large lianas		4
		The tree is heavily affected by thick lianas		5
b.	Vascular epiphytes	Estimation of the cover of vascular epiphytes:	Nominal	
		No or very few individuals observed.		0
		Less than 10 % of stem and branched cover		1
		Between 10 – 25 % of		2
		Dense mats of epiphytes may cover between 20 to 40 %		3
		Dense mats cover between 40 and 75 %. Some hanging mats.		4
		The tree is overgrown with dense and some hanging mats		5
c.	Non-vascular epiphytes	Estimation of the cover of bryophytes and lichens	Nominal	
		No or very few spots or individuals observed.		0
		Less than 10 % of stem and branched cover		1
		Between 10 – 25 % of		2
		Dense mats of epiphytes may cover between 20 to 40 %		3
		Dense mats cover between 40 and 75 %. Some hanging mats.		4
		The tree is overgrown with dense and some hanging mats		5

Appendix 2
Proximity to target score

Proximity to targets for the different indicators (variables) of CFEMI and total score for each of the 54 analysed plots. T1=Mweka transect, 18 sites, T2=Kilema transect, 20 sites, T3=Marangu transect, 16 sites, P= site number.

			Proximity to target for each indicator and total score. Unit: percent from target									
T	P	m asl	Stems	Basal Area	Height	CWidth	CWidth Sum	Cdepth	Climb Cov	Epi Cover	Species	SCORE
1	1	1590	44.0	16.1	53.2	44.2	27.0	56.6	31.1	20.5	71.4	40.5
1	2	1610	38.0	43.3	109.9	87.5	46.2	113.1	91.6	42.0	71.4	71.5
1	3	1680	64.0	43.9	75.9	53.3	47.0	75.4	90.5	93.5	83.3	69.7
1	4	1710	60.0	44.1	88.9	113.2	94.5	106.3	35.3	112.0	166.7	91.2
1	5	1740	68.0	74.9	95.0	159.8	151.1	111.0	67.9	140.0	83.3	105.7
1	6	1810	66.0	67.1	122.6	112.3	103.1	106.3	38.4	91.0	59.5	85.1
1	7	1870	78.0	65.3	92.8	73.0	79.2	96.9	32.6	109.0	107.1	81.6
1	8	1910	92.0	176.3	88.4	95.5	122.2	83.6	57.4	181.5	131.0	114.2
1	9	2150	104.0	138.0	70.1	96.3	139.3	64.1	62.6	209.5	95.2	108.8
1	10	2265	68.0	111.2	88.3	62.4	59.0	71.4	100.5	228.0	71.4	95.6
1	11	2320	58.0	148.0	80.3	89.5	72.2	73.9	101.6	257.0	47.6	103.1
1	12	2450	88.0	121.7	88.2	71.2	87.1	85.2	113.7	250.0	83.3	109.8
1	13	2500	56.0	81.3	80.7	102.8	80.1	95.7	150.5	280.5	71.4	111.0
1	14	2530	40.0	25.2	81.9	94.5	52.6	89.1	84.2	202.5	83.3	83.7
1	15	2600	146.0	91.7	77.9	46.1	93.5	52.4	71.6	311.5	59.5	105.6
1	16	2670	78.0	64.8	76.2	61.1	66.3	63.7	54.2	252.5	59.5	86.3
1	17	2740	102.0	106.3	71.3	53.7	76.1	62.2	53.7	244.0	107.1	97.4
1	18	2860	92.0	35.1	71.2	40.5	51.9	78.6	46.8	237.0	59.5	79.2
2	1	1780	14.0	12.5	39.9	11.9	2.3	45.6	60.0	50.0	35.7	30.2
2	2	1790	8.0	35.1	71.9	47.0	5.2	96.9	26.3	100.0	23.8	46.0
2	3	1810	6.0	9.5	59.7	71.6	6.0	72.5	105.3	116.5	35.7	53.6
2	4	1830	8.0	12.4	58.3	62.8	7.0	73.1	52.6	62.5	23.8	40.1
2	5	1840	24.0	24.8	60.8	39.9	13.3	70.8	52.6	129.0	71.4	54.1
2	6	1850	34.0	31.1	63.0	42.6	20.1	66.5	37.4	123.5	95.2	57.0
2	7	1870	46.0	77.5	54.9	19.8	12.6	55.0	118.9	134.5	95.2	68.3
2	8	1880	40.0	74.3	60.4	41.1	22.9	48.6	47.4	160.0	59.5	61.6
2	9	1890	38.0	43.5	68.4	118.0	62.3	73.1	61.1	208.0	59.5	81.3
2	10	1910	30.0	142.0	64.5	116.1	48.4	63.1	101.6	203.0	47.6	90.7
2	11	1930	44.0	124.7	92.4	151.4	92.6	120.6	86.3	198.0	71.4	109.0
2	12	1980	52.0	76.8	63.5	49.7	35.9	66.5	119.5	253.5	71.4	87.6
2	13	2020	64.0	90.1	88.5	202.7	180.5	110.7	115.3	278.0	83.3	134.8
2	14	2050	34.0	60.1	85.0	143.5	67.8	99.7	136.3	235.0	83.3	105.0
2	15	2110	104.0	53.6	69.9	73.4	106.2	65.6	41.6	193.0	83.3	87.8
2	16	2300	74.0	50.0	79.4	104.3	107.4	91.7	81.1	185.0	71.4	93.8
2	17	2430	64.0	80.5	97.8	123.9	110.3	108.2	144.7	334.5	83.3	127.5
2	18	2450	84.0	56.4	74.8	53.0	61.9	86.9	160.5	79.5	71.4	80.9
2	19	2580	74.0	91.9	109.8	70.4	72.4	91.6	25.8	259.5	47.6	93.7
2	20	2670	216.0	72.9	67.3	30.3	91.0	62.9	33.2	158.5	95.2	91.9

T	P	m asl	Stems	Basal Area	Height	CWidth	CWidth Sum	Cdepth	Climb Cov	Epi Cover	Species	SCORE
3	1	1820	56.0	28.9	40.8	26.3	20.5	40.8	45.3	125.0	47.6	47.9
3	2	1860	72.0	66.9	64.3	88.6	88.7	65.0	96.3	158.5	95.2	88.4
3	3	1940	104.0	54.3	66.9	40.9	59.2	52.2	71.1	196.0	83.3	80.9
3	4	2020	124.0	78.7	92.2	46.3	79.9	76.6	47.4	146.0	59.5	83.4
3	5	2100	102.0	81.7	79.7	71.2	101.0	70.8	83.7	236.0	71.4	99.7
3	6	2160	152.0	52.9	67.7	28.6	60.4	65.4	93.7	201.0	154.8	97.4
3	7	2240	124.0	72.0	65.4	45.5	78.5	69.0	97.4	284.5	119.0	106.1
3	8	2280	178.0	62.5	61.8	22.1	54.8	61.0	77.4	241.5	119.0	97.6
3	9	2330	84.0	87.1	90.7	81.9	95.7	88.1	41.6	280.0	59.5	100.9
3	10	2390	80.0	88.0	92.3	80.5	89.6	98.0	112.1	335.0	71.4	116.3
3	11	2410	138.0	62.8	60.7	39.1	75.0	60.5	50.5	288.5	107.1	98.0
3	12	2450	132.0	64.4	71.3	48.3	88.6	73.2	38.4	282.5	142.9	104.6
3	13	2540	320.0	48.0	43.8	7.2	32.1	38.7	13.2	190.5	47.6	82.3
3	14	2580	650.0	96.3	42.0	6.6	60.0	33.2	8.4	154.0	59.5	123.3
3	15	2610	4.0	13.5	79.2	41.6	2.3	74.8	105.3	350.0	23.8	77.2
3	16	2670	48.0	67.2	61.8	48.0	32.1	62.3	50.5	229.0	83.3	75.8
Aver.		**2155**	**88.3**	**68.5**	**74.5**	**69.5**	**66.5**	**75.7**	**72.7**	**193.0**	**77.2**	**87.3**

Doctoral theses in Biology

Norwegian University of Science and Technology

Department of Biology

Year	Name	Degree	Title
1974	Tor-Henning Iversen	Dr. philos Botany	The roles of statholiths, auxin transport, and auxin metabolism in root gravitropism
1978	Tore Slagsvold	Dr. philos. Zoology	Breeding events of birds in relation to spring temperature and environmental phenology.
1978	Egil Sakshaug	Dr.philos Botany	"The influence of environmental factors on the chemical composition of cultivated and natural populations of marine phytoplankton"
1980	Arnfinn Langeland	Dr. philos. Zoology	Interaction between fish and zooplankton populations and their effects on the material utilization in a freshwater lake.
1980	Helge Reinertsen	Dr. philos Botany	The effect of lake fertilization on the dynamics and stability of a limnetic ecosystem with special reference to the phytoplankton
1982	Gunn Mari Olsen	Dr. scient Botany	Gravitropism in roots of *Pisum sativum* and *Arabidopsis thaliana*
1982	Dag Dolmen	Dr. philos. Zoology	Life aspects of two sympartic species of newts (*Triturus, Amphibia*) in Norway, with special emphasis on their ecological niche segregation.
1984	Eivin Røskaft	Dr. philos. Zoology	Sociobiological studies of the rook *Corvus frugilegus.*
1984	Anne Margrethe Cameron	Dr. scient Botany	Effects of alcohol inhalation on levels of circulating testosterone, follicle stimulating hormone and luteinzing hormone in male mature rats
1984	Asbjørn Magne Nilsen	Dr. scient Botany	Alveolar macrophages from expectorates – Biological monitoring of workers exosed to occupational air pollution. An evaluation of the AM-test
1985	Jarle Mork	Dr. philos. Zoology	Biochemical genetic studies in fish.
1985	John Solem	Dr. philos. Zoology	Taxonomy, distribution and ecology of caddisflies (*Trichoptera*) in the Dovrefjell mountains.
1985	Randi E. Reinertsen	Dr. philos. Zoology	Energy strategies in the cold: Metabolic and thermoregulatory adaptations in small northern birds.
1986	Bernt-Erik Sæther	Dr. philos. Zoology	Ecological and evolutionary basis for variation in reproductive traits of some vertebrates: A comparative approach.
1986	Torleif Holthe	Dr. philos. Zoology	Evolution, systematics, nomenclature, and zoogeography in the polychaete orders *Oweniimorpha* and *Terebellomorpha*, with special reference to the Arctic and Scandinavian fauna.
1987	Helene Lampe	Dr. scient. Zoology	The function of bird song in mate attraction and territorial defence, and the importance of song repertoires.
1987	Olav Hogstad	Dr. philos. Zoology	Winter survival strategies of the Willow tit *Parus montanus*.

1987 Jarle Inge Holten	Dr. philos Botany	Autecological investigations along a coust-inland transect at Nord-Møre, Central Norway
1987 Rita Kumar	Dr. scient Botany	Somaclonal variation in plants regenerated from cell cultures of *Nicotiana sanderae* and *Chrysanthemum morifolium*
1987 Bjørn Åge Tømmerås	Dr. scient. Zoology	Olfaction in bark beetle communities: Interspecific interactions in regulation of colonization density, predator - prey relationship and host attraction.
1988 Hans Christian Pedersen	Dr. philos. Zoology	Reproductive behaviour in willow ptarmigan with special emphasis on territoriality and parental care.
1988 Tor G. Heggberget	Dr. philos. Zoology	Reproduction in Atlantic Salmon (*Salmo salar*): Aspects of spawning, incubation, early life history and population structure.
1988 Marianne V. Nielsen	Dr. scient. Zoology	The effects of selected environmental factors on carbon allocation/growth of larval and juvenile mussels (*Mytilus edulis*).
1988 Ole Kristian Berg	Dr. scient. Zoology	The formation of landlocked Atlantic salmon (*Salmo salar* L.).
1989 John W. Jensen	Dr. philos. Zoology	Crustacean plankton and fish during the first decade of the manmade Nesjø reservoir, with special emphasis on the effects of gill nets and salmonid growth.
1989 Helga J. Vivås	Dr. scient. Zoology	Theoretical models of activity pattern and optimal foraging: Predictions for the Moose *Alces alces*.
1989 Reidar Andersen	Dr. scient. Zoology	Interactions between a generalist herbivore, the moose *Alces alces*, and its winter food resources: a study of behavioural variation.
1989 Kurt Ingar Draget	Dr. scient Botany	Alginate gel media for plant tissue culture,
1990 Bengt Finstad	Dr. scient. Zoology	Osmotic and ionic regulation in Atlantic salmon, rainbow trout and Arctic charr: Effect of temperature, salinity and season.
1990 Hege Johannesen	Dr. scient. Zoology	Respiration and temperature regulation in birds with special emphasis on the oxygen extraction by the lung.
1990 Åse Krøkje	Dr. scient Botany	The mutagenic load from air pollution at two work-places with PAH-exposure measured with Ames Salmonella/microsome test
1990 Arne Johan Jensen	Dr. philos. Zoology	Effects of water temperature on early life history, juvenile growth and prespawning migrations of Atlantic salmion (*Salmo salar*) and brown trout (*Salmo trutta*): A summary of studies in Norwegian streams.
1990 Tor Jørgen Almaas	Dr. scient. Zoology	Pheromone reception in moths: Response characteristics of olfactory receptor neurons to intra- and interspecific chemical cues.
1990 Magne Husby	Dr. scient. Zoology	Breeding strategies in birds: Experiments with the Magpie *Pica pica*.
1991 Tor Kvam	Dr. scient. Zoology	Population biology of the European lynx (*Lynx lynx*) in Norway.
1991 Jan Henning L'Abêe Lund	Dr. philos. Zoology	Reproductive biology in freshwater fish, brown trout *Salmo trutta* and roach *Rutilus rutilus* in particular.
1991 Asbjørn Moen	Dr. philos Botany	The plant cover of the boreal uplands of Central Norway. I. Vegetation ecology of Sølendet nature reserve; haymaking fens and birch woodlands
1991 Else Marie Løbersli	Dr. scient Botany	Soil acidification and metal uptake in plants

1991	Trond Nordtug	Dr. scient. Zoology	Reflctometric studies of photomechanical adaptation in superposition eyes of arthropods.
1991	Thyra Solem	Dr. scient Botany	Age, origin and development of blanket mires in Central Norway
1991	Odd Terje Sandlund	Dr. philos. Zoology	The dynamics of habitat use in the salmonid genera *Coregonus* and *Salvelinus*: Ontogenic niche shifts and polymorphism.
1991	Nina Jonsson	Dr. philos.	Aspects of migration and spawning in salmonids.
1991	Atle Bones	Dr. scient Botany	Compartmentation and molecular properties of thioglucoside glucohydrolase (myrosinase)
1992	Torgrim Breiehagen	Dr. scient. Zoology	Mating behaviour and evolutionary aspects of the breeding system of two bird species: the Temminck's stint and the Pied flycatcher.
1992	Anne Kjersti Bakken	Dr. scient Botany	The influence of photoperiod on nitrate assimilation and nitrogen status in timothy (*Phleum pratense* L.)
1992	Tycho Anker-Nilssen	Dr. scient. Zoology	Food supply as a determinant of reproduction and population development in Norwegian Puffins *Fratercula arctica*
1992	Bjørn Munro Jenssen	Dr. philos. Zoology	Thermoregulation in aquatic birds in air and water: With special emphasis on the effects of crude oil, chemically treated oil and cleaning on the thermal balance of ducks.
1992	Arne Vollan Aarset	Dr. philos. Zoology	The ecophysiology of under-ice fauna: Osmotic regulation, low temperature tolerance and metabolism in polar crustaceans.
1993	Geir Slupphaug	Dr. scient Botany	Regulation and expression of uracil-DNA glycosylase and O^6-methylguanine-DNA methyltransferase in mammalian cells
1993	Tor Fredrik Næsje	Dr. scient. Zoology	Habitat shifts in coregonids.
1993	Yngvar Asbjørn Olsen	Dr. scient. Zoology	Cortisol dynamics in Atlantic salmon, *Salmo salar* L.: Basal and stressor-induced variations in plasma levels ans some secondary effects.
1993	Bård Pedersen	Dr. scient Botany	Theoretical studies of life history evolution in modular and clonal organisms
1993	Ole Petter Thangstad	Dr. scient Botany	Molecular studies of myrosinase in Brassicaceae
1993	Thrine L. M. Heggberget	Dr. scient. Zoology	Reproductive strategy and feeding ecology of the Eurasian otter *Lutra lutra*.
1993	Kjetil Bevanger	Dr. scient. Zoology	Avian interactions with utility structures, a biological approach.
1993	Kåre Haugan	Dr. scient Bothany	Mutations in the replication control gene trfA of the broad host-range plasmid RK2
1994	Peder Fiske	Dr. scient. Zoology	Sexual selection in the lekking great snipe (*Gallinago media*): Male mating success and female behaviour at the lek.
1994	Kjell Inge Reitan	Dr. scient Botany	Nutritional effects of algae in first-feeding of marine fish larvae
1994	Nils Røv	Dr. scient. Zoology	Breeding distribution, population status and regulation of breeding numbers in the northeast-Atlantic Great Cormorant *Phalacrocorax carbo carbo*.
1994	Annette-Susanne Hoepfner	Dr. scient Botany	Tissue culture techniques in propagation and breeding of Red Raspberry (*Rubus idaeus* L.)

1994 Inga Elise Bruteig	Dr. scient Bothany	Distribution, ecology and biomonitoring studies of epiphytic lichens on conifers
1994 Geir Johnsen	Dr. scient Botany	Light harvesting and utilization in marine phytoplankton: Species-specific and photoadaptive responses
1994 Morten Bakken	Dr. scient. Zoology	Infanticidal behaviour and reproductive performance in relation to competition capacity among farmed silver fox vixens, *Vulpes vulpes*.
1994 Arne Moksnes	Dr. philos. Zoology	Host adaptations towards brood parasitism by the Cockoo.
1994 Solveig Bakken	Dr. scient Bothany	Growth and nitrogen status in the moss *Dicranum majus* Sm. as influenced by nitrogen supply
1995 Olav Vadstein	Dr. philos Botany	The role of heterotrophic planktonic bacteria in the cycling of phosphorus in lakes: Phosphorus requirement, competitive ability and food web interactions.
1995 Hanne Christensen	Dr. scient. Zoology	Determinants of Otter *Lutra lutra* distribution in Norway: Effects of harvest, polychlorinated biphenyls (PCBs), human population density and competition with mink *Mustela vision*.
1995 Svein Håkon Lorentsen	Dr. scient. Zoology	Reproductive effort in the Antarctic Petrel *Thalassoica antarctica*; the effect of parental body size and condition.
1995 Chris Jørgen Jensen	Dr. scient. Zoology	The surface electromyographic (EMG) amplitude as an estimate of upper trapezius muscle activity
1995 Martha Kold Bakkevig	Dr. scient. Zoology	The impact of clothing textiles and construction in a clothing system on thermoregulatory responses, sweat accumulation and heat transport.
1995 Vidar Moen	Dr. scient. Zoology	Distribution patterns and adaptations to light in newly introduced populations of *Mysis relicta* and constraints on Cladoceran and Char populations.
1995 Hans Haavardsholm Blom	Dr. philos Bothany	A revision of the *Schistidium apocarpum* complex in Norway and Sweden.
1996 Jorun Skjærmo	Dr. scient Botany	Microbial ecology of early stages of cultivated marine fish; inpact fish-bacterial interactions on growth and survival of larvae.
1996 Ola Ugedal	Dr. scient. Zoology	Radiocesium turnover in freshwater fishes
1996 Ingibjørg Einarsdottir	Dr. scient. Zoology	Production of Atlantic salmon (*Salmo salar*) and Arctic charr (*Salvelinus alpinus*): A study of some physiological and immunological responses to rearing routines.
1996 Christina M. S. Pereira	Dr. scient. Zoology	Glucose metabolism in salmonids: Dietary effects and hormonal regulation.
1996 Jan Fredrik Børseth	Dr. scient. Zoology	The sodium energy gradients in muscle cells of *Mytilus edulis* and the effects of organic xenobiotics.
1996 Gunnar Henriksen	Dr. scient. Zoology	Status of Grey seal *Halichoerus grypus* and Harbour seal *Phoca vitulina* in the Barents sea region.
1997 Gunvor Øie	Dr. scient Bothany	Eevalution of rotifer *Brachionus plicatilis* quality in early first feeding of turbot *Scophtalmus maximus* L. larvae.
1997 Håkon Holien	Dr. scient Botany	Studies of lichens in spurce forest of Central Norway. Diversity, old growth species and the relationship to site and stand parameters.
1997 Ole Reitan	Dr. scient. Zoology	Responses of birds to habitat disturbance due to damming.

1997 Jon Arne Grøttum	Dr. scient. Zoology	Physiological effects of reduced water quality on fish in aquaculture.
1997 Per Gustav Thingstad	Dr. scient. Zoology	Birds as indicators for studying natural and human-induced variations in the environment, with special emphasis on the suitability of the Pied Flycatcher.
1997 Torgeir Nygård	Dr. scient. Zoology	Temporal and spatial trends of pollutants in birds in Norway: Birds of prey and Willow Grouse used as Biomonitors.
1997 Signe Nybø	Dr. scient. Zoology	Impacts of long-range transported air pollution on birds with particular reference to the dipper *Cinclus cinclus* in southern Norway.
1997 Atle Wibe	Dr. scient. Zoology	Identification of conifer volatiles detected by receptor neurons in the pine weevil (*Hylobius abietis*), analysed by gas chromatography linked to electrophysiology and to mass spectrometry.
1997 Rolv Lundheim	Dr. scient. Zoology	Adaptive and incidental biological ice nucleators.
1997 Arild Magne Landa	Dr. scient. Zoology	Wolverines in Scandinavia: ecology, sheep depredation and conservation.
1997 Kåre Magne Nielsen	Dr. scient Botany	An evolution of possible horizontal gene transfer from plants to sail bacteria by studies of natural transformation in *Acinetobacter calcoacetius*.
1997 Jarle Tufto	Dr. scient. Zoology	Gene flow and genetic drift in geographically structured populations: Ecological, population genetic, and statistical models
1997 Trygve Hesthagen	Dr. philos. Zoology	Population responces of Arctic charr (*Salvelinus alpinus* (L.)) and brown trout (*Salmo trutta* L.) to acidification in Norwegian inland waters
1997 Trygve Sigholt	Dr. philos. Zoology	Control of Parr-smolt transformation and seawater tolerance in farmed Atlantic Salmon (*Salmo salar*) Effects of photoperiod, temperature, gradual seawater acclimation, NaCl and betaine in the diet
1997 Jan Østnes	Dr. scient. Zoology	Cold sensation in adult and neonate birds
1998 Seethaledsumy Visvalingam	Dr. scient Botany	Influence of environmental factors on myrosinases and myrosinase-binding proteins.
1998 Thor Harald Ringsby	Dr. scient. Zoology	Variation in space and time: The biology of a House sparrow metapopulation
1998 Erling Johan Solberg	Dr. scient. Zoology	Variation in population dynamics and life history in a Norwegian moose (*Alces alces*) population: consequences of harvesting in a variable environment
1998 Sigurd Mjøen Saastad	Dr. scient Botany	Species delimitation and phylogenetic relationships between the Sphagnum recurvum complex (Bryophyta): genetic variation and phenotypic plasticity.
1998 Bjarte Mortensen	Dr. scient Botany	Metabolism of volatile organic chemicals (VOCs) in a head liver S9 vial equilibration system in vitro.
1998 Gunnar Austrheim	Dr. scient Botany	Plant biodiversity and land use in subalpine grasslands. – A conservtaion biological approach.
1998 Bente Gunnveig Berg	Dr. scient. Zoology	Encoding of pheromone information in two related moth species
1999 Kristian Overskaug	Dr. scient. Zoology	Behavioural and morphological characteristics in Northern Tawny Owls *Strix aluco*: An intra- and interspecific comparative approach

1999	Hans Kristen Stenøien	Dr. scient Bothany	Genetic studies of evolutionary processes in various populations of nonvascular plants (mosses, liverworts and hornworts)
1999	Trond Arnesen	Dr. scient Botany	Vegetation dynamics following trampling and burning in the outlying haylands at Sølendet, Central Norway.
1999	Ingvar Stenberg	Dr. scient. Zoology	Habitat selection, reproduction and survival in the White-backed Woodpecker *Dendrocopos leucotos*
1999	Stein Olle Johansen	Dr. scient Botany	A study of driftwood dispersal to the Nordic Seas by dendrochronology and wood anatomical analysis.
1999	Trina Falck Galloway	Dr. scient. Zoology	Muscle development and growth in early life stages of the Atlantic cod (*Gadus morhua* L.) and Halibut (*Hippoglossus hippoglossus* L.)
1999	Torbjørn Forseth	Dr. scient. Zoology	Bioenergetics in ecological and life history studies of fishes.
1999	Marianne Giæver	Dr. scient. Zoology	Population genetic studies in three gadoid species: blue whiting (*Micromisistius poutassou*), haddock (*Melanogrammus aeglefinus*) and cod (*Gradus morhua*) in the North-East Atlantic
1999	Hans Martin Hanslin	Dr. scient Botany	The impact of environmental conditions of density dependent performance in the boreal forest bryophytes *Dicranum majus*, *Hylocomium splendens*, *Plagiochila asplenigides*, *Ptilium crista-castrensis* and *Rhytidiadelphus lokeus*.
1999	Ingrid Bysveen Mjølnerød	Dr. scient. Zoology	Aspects of population genetics, behaviour and performance of wild and farmed Atlantic salmon (*Salmo salar*) revealed by molecular genetic techniques
1999	Else Berit Skagen	Dr. scient Botany	The early regeneration process in protoplasts from *Brassica napus* hypocotyls cultivated under various g-forces
1999	Stein-Are Sæther	Dr. philos. Zoology	Mate choice, competition for mates, and conflicts of interest in the Lekking Great Snipe
1999	Katrine Wangen Rustad	Dr. scient. Zoology	Modulation of glutamatergic neurotransmission related to cognitive dysfunctions and Alzheimer's disease
1999	Per Terje Smiseth	Dr. scient. Zoology	Social evolution in monogamous families: mate choice and conflicts over parental care in the Bluethroat (*Luscinia s. svecica*)
1999	Gunnbjørn Bremset	Dr. scient. Zoology	Young Atlantic salmon (*Salmo salar* L.) and Brown trout (*Salmo trutta* L.) inhabiting the deep pool habitat, with special reference to their habitat use, habitat preferences and competitive interactions
1999	Frode Ødegaard	Dr. scient. Zoology	Host spesificity as parameter in estimates of arhrophod species richness
1999	Sonja Andersen	Dr. scient Bothany	Expressional and functional analyses of human, secretory phospholipase A2
2000	Ingrid Salvesen, I	Dr. scient Botany	Microbial ecology in early stages of marine fish: Development and evaluation of methods for microbial management in intensive larviculture
2000	Ingar Jostein Øien	Dr. scient. Zoology	The Cuckoo (*Cuculus canorus*) and its host: adaptions and counteradaptions in a coevolutionary arms race
2000	Pavlos Makridis	Dr. scient Botany	Methods for the microbial econtrol of live food used for the rearing of marine fish larvae
2000	Sigbjørn Stokke	Dr. scient. Zoology	Sexual segregation in the African elephant (*Loxodonta africana*)

2000 Odd A. Gulseth	Dr. philos. Zoology	Seawater tolerance, migratory behaviour and growth of Charr, (*Salvelinus alpinus*), with emphasis on the high Arctic Dieset charr on Spitsbergen, Svalbard
2000 Pål A. Olsvik	Dr. scient. Zoology	Biochemical impacts of Cd, Cu and Zn on brown trout (*Salmo trutta*) in two mining-contaminated rivers in Central Norway
2000 Sigurd Einum	Dr. scient. Zoology	Maternal effects in fish: Implications for the evolution of breeding time and egg size
2001 Jan Ove Evjemo	Dr. scient. Zoology	Production and nutritional adaptation of the brine shrimp *Artemia* sp. as live food organism for larvae of marine cold water fish species
2001 Olga Hilmo	Dr. scient Botany	Lichen response to environmental changes in the managed boreal forset systems
2001 Ingebrigt Uglem	Dr. scient. Zoology	Male dimorphism and reproductive biology in corkwing wrasse (*Symphodus melops* L.)
2001 Bård Gunnar Stokke	Dr. scient. Zoology	Coevolutionary adaptations in avian brood parasites and their hosts
2002 Ronny Aanes	Dr. scient	Spatio-temporal dynamics in Svalbard reindeer (*Rangifer tarandus platyrhynchus*)
2002 Mariann Sandsund	Dr. scient. Zoology	Exercise- and cold-induced asthma. Respiratory and thermoregulatory responses
2002 Dag-Inge Øien	Dr. scient Botany	Dynamics of plant communities and populations in boreal vegetation influenced by scything at Sølendet, Central Norway
2002 Frank Rosell	Dr. scient. Zoology	The function of scent marking in beaver (*Castor fiber*)
2002 Janne Østvang	Dr. scient Botany	The Role and Regulation of Phospholipase A_2 in Monocytes During Atherosclerosis Development
2002 Terje Thun	Dr.philos Biology	Dendrochronological constructions of Norwegian conifer chronologies providing dating of historical material
2002 Birgit Hafjeld Borgen	Dr. scient Biology	Functional analysis of plant idioblasts (Myrosin cells) and their role in defense, development and growth
2002 Bård Øyvind Solberg	Dr. scient Biology	Effects of climatic change on the growth of dominating tree species along major environmental gradients
2002 Per Winge	Dr. scient Biology	The evolution of small GTP binding proteins in cellular organisms. Studies of RAC GTPases in *Arabidopsis thaliana* and
2002 Henrik Jensen	Dr. scient Biology	Causes and consequenses of individual variation in fitness-related traits in house sparrows
2003 Jens Rohloff	Dr. philos Biology	Cultivation of herbs and medicinal plants in Norway – Essential oil production and quality control
2003 Åsa Maria O. Espmark Wibe	Dr. scient Biology	Behavioural effects of environmental pollution in threespine stickleback *Gasterosteus aculeatur* L.
2003 Dagmar Hagen	Dr. scient Biology	Assisted recovery of disturbed arctic and alpine vegetation – an integrated approach
2003 Bjørn Dahle	Dr. scient Biology	Reproductive strategies in Scandinavian brown bears
2003 Cyril Lebogang Taolo	Dr. scient Biology	Population ecology, seasonal movement and habitat use of the African buffalo (*Syncerus caffer*) in Chobe National Park, Botswana
2003 Marit Stranden	Dr.scient Biology	Olfactory receptor neurones specified for the same odorants in three related Heliothine species (*Helicoverpa armigera, Helicoverpa assulta* and *Heliothis virescens*)

2003	Kristian Hassel	Dr.scient Biology	Life history characteristics and genetic variation in an expanding species, *Pogonatum dentatum*
2003	David Alexander Rae	Dr.scient Biology	Plant- and invertebrate-community responses to species interaction and microclimatic gradients in alpine and Artic environments
2003	Åsa A Borg	Dr.scient Biology	Sex roles and reproductive behaviour in gobies and guppies: a female perspective
2003	Eldar Åsgard Bendiksen	Dr.scient Biology	Environmental effects on lipid nutrition of farmed Atlantic salmon (*Salmo Salar* L.) parr and smolt
2004	Torkild Bakken	Dr.scient Biology	A revision of Nereidinae (Polychaeta, Nereididae)
2004	Ingar Pareliussen	Dr.scient Biology	Natural and Experimental Tree Establishment in a Fragmented Forest, Ambohitantely Forest Reserve, Madagascar
2004	Tore Brembu	Dr.scient Biology	Genetic, molecular and functional studies of RAC GTPases and the WAVE-like regulatory protein complex in *Arabidopsis thaliana*
2004	Liv S. Nilsen	Dr.scient Biology	Coastal heath vegetation on central Norway; recent past, present state and future possibilities
2004	Hanne T. Skiri	Dr.scient Biology	Olfactory coding and olfactory learning of plant odours in heliothine moths. An anatomical, physiological and behavioural study of three related species (*Heliothis virescens, Helicoverpa armigera* and *Helicoverpa assulta*).
2004	Lene Østby	Dr.scient Biology	Cytochrome P4501A (CYP1A) induction and DNA adducts as biomarkers for organic pollution in the natural environment
2004	Emmanuel J. Gerreta	Dr. philos Biology	The Importance of Water Quality and Quantity in the Tropical Ecosystems, Tanzania
2004	Linda Dalen	Dr.scient Biology	Dynamics of Mountain Birch Treelines in the Scandes Mountain Chain, and Effects of Climate Warming
2004	Lisbeth Mehli	Dr.scient Biology	Polygalacturonase-inhibiting protein (PGIP) in cultivated strawberry (*Fragaria* x *ananassa*): characterisation and induction of the gene following fruit infection by *Botrytis cinerea*
2004	Børge Moe	Dr.scient Biology	Energy-Allocation in Avian Nestlings Facing Short-Term Food Shortage
2005	Matilde Skogen Chauton	Dr.scient Biology	Metabolic profiling and species discrimination from High-Resolution Magic Angle Spinning NMR analysis of whole-cell samples
2005	Sten Karlsson	Dr.scient Biology	Dynamics of Genetic Polymorphisms
2005	Terje Bongard	Dr.scient Biology	Life History strategies, mate choice, and parental investment among Norwegians over a 300-year period
2005	Tonette Røstelien	PhD Biology	Functional characterisation of olfactory receptor neurone types in heliothine moths
2005	Erlend Kristiansen	Dr.scient Biology	Studies on antifreeze proteins
2005	Eugen G. Sørmo	Dr.scient Biology	Organochlorine pollutants in grey seal (*Halichoerus grypus*) pups and their impact on plasma thyrid hormone and vitamin A concentrations.

2005	Christian Westad	Dr.scient Biology	Motor control of the upper trapezius
2005	Lasse Mork Olsen	PhD Biology	Interactions between marine osmo- and phagotrophs in different physicochemical environments
2005	Åslaug Viken	PhD Biology	Implications of mate choice for the management of small populations
2005	Ariaya Hymete Sahle Dingle	PhD Biology	Investigation of the biological activities and chemical constituents of selected *Echinops* spp. growing in Ethiopia
2005	Anders Gravbrøt Finstad	PhD Biology	Salmonid fishes in a changing climate: The winter challenge
2005	Shimane Washington Makabu	PhD Biology	Interactions between woody plants, elephants and other browsers in the Chobe Riverfront, Botswana
2005	Kjartan Østbye	Dr.scient Biology	The European whitefish *Coregonus lavaretus* (L.) species complex: historical contingency and adaptive radiation
2006	Kari Mette Murvoll	PhD Biology	Levels and effects of persistent organic pollutans (POPs) in seabirds Retinoids and α-tocopherol – potential biomakers of POPs in birds?
2006	Ivar Herfindal	Dr.scient Biology	Life history consequences of environmental variation along ecological gradients in northern ungulates
2006	Nils Egil Tokle	Phd Biology	Are the ubiquitous marine copepods limited by food or predation? Experimental and field-based studies with main focus on *Calanus finmarchicus*
2006	Jan Ove Gjershaug	Dr.philos Biology	Taxonomy and conservation status of some booted eagles in south-east Asia
2006	Jon Kristian Skei	Dr.scient Biology	Conservation biology and acidification problems in the breeding habitat of amphibians in Norway
2006	Johanna Järnegren	PhD Biology	Acesta Oophaga and Acesta Excavata – a study of hidden biodiversity
2006	Bjørn Henrik Hansen	PhD Biology	Metal-mediated oxidative stress responses in brown trout (*Salmo trutta*) from mining contaminated rivers in Central Norway
2006	Vidar Grøtan	PhD Biology	Temporal and spatial effects of climate fluctuations on population dynamics of vertebrates
2006	Jafari R Kideghesho	phD Biology	Wildlife conservation and local land use conflicts in western Serengeti, Corridor Tanzania
2006	Anna Maria Billing	PhD Biology	Reproductive decisions in the sex role reversed pipefish *Syngnathus typhle*: when and how to invest in reproduction
2006	Henrik Pärn	PhD Biology	Female ornaments and reproductive biology in the bluethroat
2006	Anders J. Fjellheim	PhD Biology	Selection and administration of probiotic bacteria to marine fish larvae
2006	P. Andreas Svensson	phD Biology	Female coloration, egg carotenoids and reproductive success: gobies as a model system
2007	Sindre A. Pedersen	PhD Biology	Metal binding proteins and antifreeze proteins in the beetle *Tenebrio molitor* - a study on possible competition for the semi-essential amino acid cysteine

2007	Kasper Hancke	PhD Biology	Photosynthetic responses as a function of light and temperature: Field and laboratory studies on marine microalgae
2007	Tomas Holmern	PhD Biology	Bushmeat hunting in the western Serengeti: Implications for community-based conservation
2007	Kari Jørgensen	PhD Biology	Functional tracing of gustatory receptor neurons in the CNS and chemosensory learning in the moth *Heliothis virescens*
2007	Stig Ulland	PhD Biology	Functional Characterisation of Olfactory Receptor Neurons in the Cabbage Moth, */Mamestra Brassicae/* L. (Lepidoptera, Noctuidae). Gas Chromatography Linked to Single Cell Recordings and Mass Spectrometry
2007	Snorre Henriksen	PhD Biology	Spatial and temporal variation in herbivore resources at northern latitudes
2007	Roelof Frans May	PhD Biology	Spatial Ecology of Wolverines in Scandinavia
2007	Vedasto Gabriel Ndibalema	PhD Biology	Demographic variation, distribution and habitat use between wildebeest sub-populations in the Serengeti National Park, Tanzania
2007	Julius William Nyahongo	PhD Biology	Depredation of Livestock by wild Carnivores and Illegal Utilization of Natural Resources by Humans in the Western Serengeti, Tanzania
2007	Shombe Ntaraluka Hassan	PhD Biology	Effects of fire on large herbivores and their forage resources in Serengeti, Tanzania
2007	Per-Arvid Wold	PhD Biology	Functional development and response to dietary treatment in larval Atlantic cod *(Gadus morhua* L.) Focus on formulated diets and early weaning
2007	Anne Skjetne Mortensen	PhD Biology	Toxicogenomics of Aryl Hydrocarbon- and Estrogen Receptor Interactions in Fish: Mechanisms and Profiling of Gene Expression Patterns in Chemical Mixture Exposure Scenarios
2008	Brage Bremset Hansen	PhD Biology	The Svalbard reindeer (*Rangifer tarandus platyrhynchus*) and its food base: plant-herbivore interactions in a high-arctic ecosystem
2008	Jiska van Dijk	PhD Biology	Wolverine foraging strategies in a multiple-use landscape
2008	Flora John Magige	PhD Biology	The ecology and behaviour of the Masai Ostrich (Struthio camelus massaicus) in the Serengeti Ecosystem, Tanzania
2008	Bernt Rønning	PhD Biology	Sources of inter- and intra-individual variation in basal metabolic rate in the zebra finch, */Taeniopygia guttata/*
2008	Sølvi Wehn	PhD Biology	Biodiversity dynamics in semi-natural mountain landscapes. - A study of consequences of changed agricultural practices in Eastern Jotunheimen
2008	Trond Moxness Kortner	PhD Biology	"The Role of Androgens on previtellogenic oocyte growth in Atlantic cod (*Gadus morhu/*): Identification and patterns of differentially expressed genes in relation to Stereological Evaluations"

2008	Katarina Mariann Jørgensen	Dr.Scient Biology	The role of platelet activating factor in activation of growth arrested keratinocytes and re-epithelialisation
2008	Tommy Jørstad	PhD Biology	Statistical Modelling of Gene Expression Data
2008	Anna Kusnierczyk	PhD Bilogy	*Arabidopsis thaliana* Responses to Aphid Infestation
2008	Jussi Evertsen	PhD Biology	Herbivore sacoglossans with photosynthetic chloroplasts