Chapter 3
Complexity Theory and Forest Resource Economics

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Abstract A complex systems approach is used to test economic and moral values of actors, and their interactions with institutions towards sustainable forest management (SFM) in Mount Kilimanjaro, Tanzania. Chaos theory interpretations reveal that formal and informal organizations and institutions they promote serve as attractors that shape evolving preferences of actors—foresters, environmentalists, park authorities, entrepreneurs, and local communities—towards SFM. Diverse and dynamic preferences of heterogeneous actors including both self-interest and altruistic behaviors are observed; particularly, many economic and moral values oscillate in positive basin of attraction/optimization—indicating their complimentary nature. Thus, the economic agents presented in this analysis behave in a manner of the so called 'socially-rational agent', rather than self-interest maximizing agents of the Faustmann's model. Institutionally, there are informal advocacy coalitions with actors from different formal work organizations, but with shared values towards SFM. This is coupled with strong positive valuation of co-operative (participatory and collaborative) arrangements of SFM vis-à-vis conventional centralized forest management. While SFM values limit cycles oscillate in more stable and desirable basins of attraction, institutions limit cycles show more chaos. The latter outcome suggests that continued SFM institutional reforms, rather that mere value sensitization, are critical ingredients towards SFM.

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3.1 Introduction

Economics of 'sustainable forestry' has a long history since the classic land rent theory based on maximizing soil expectation value of perpetual timber rotations (Faustmann 1849) and optimum financial rotation (Pressler 1860). According to the Faustmann's land rent-theory, it is optimal to harvest a stand when the rate of change of its value with respect to time is equal to the interest on the value of the standing trees plus interest on the value of the forestland (Tahvonen and Viitala 2006). This outcome, however, requires perfect markets for capital, timber, and other inputs; no uncertainty; and forest owners without environmental preferences (Samuelson 1976; Johnson and Löfgren 1985). While classical land rent theory is based on timber only, current forest valuation and management require incorporation of diverse values provided by forests (Turner et al. 2003). Yet, the foundation of the current forest economic thought on neo-classical economics retains many land rent theory features of efficiency and control. For example, the assumptions of fixed tastes and homogeneous, super-rational, independent agents competing to maximize their self-interests are retained (Colander 2005; Kant 2005). The resulting 'single equilibrium' is, under the right conditions, supposed to also maximize social welfare. These features render the classical land rent theory inadequate in addressing sustainable forest management (SFM), which is characterized by multiple agents (in present and future generations) with diverse and dynamic economic, social and environmental preferences (Kant and Lee 2004; Kijazi and Kant 2010).

Analytically, the above features of the land rent theory and neo-classical valuations fit neatly into linear algebra and calculus framework, which underlies most analytical tools of what Colander (2005) calls the "efficiency story". However, SFM features do not fit-well with the efficiency story. Rather, SFM is characterized by complexity story, which views change (e.g. progress towards SFM) as an evolutionary process occurring concurrently at multiple levels (Colander 2005). Accordingly, policy is affecting mutually-dependent variables some of which are gradually moving while others are rapidly moving. Thus, rather than solely searching for optima, like in the case of land rent theory, SFM analyst need to look for early indicators of switch points that will fundamentally change the nature of the system (ibid.). Also, in contrast to the efficiency story, economics of SFM are characterized by requirements for co-operative arrangements, featuring both self-interest and altruistic behaviors of agents (Kant 2005; Kijazi and Kant 2010). This entails complementarities of economic and moral values; plus, diverse and dynamic preferences of heterogeneous agents (Colander 2005; Kant 2005). Non-linear systems approaches that consider complex interactions between social, economic and natural systems are more appropriate for such features (Kijazi 2007). Thus,

complexity theory, rather than the land rent theory, may be more suited to the analysis of SFM matrix involving heterogeneous agents with diverse preferences.

In this chapter, we use complexity theory to analyze a SFM forest-actor matrix including economic, social, and environmental values, and we examine early indicators of switch points towards SFM in Mount Kilimanjaro eco-systems of Tanzania. By using complex system model, we are not concerned about equilibrium. Our interest is basins of attractions that govern behaviours of the forest-actors and their interactions with their eco-system towards SFM. Thus, in our analysis nonlinearities are accepted, and phase transition jumps as the system evolves are anticipated (Priesmeyer 1992; Dent 1994; Dooley and Van de Van 1999). We analyze SFM from the forest economics perspective, within a complex system of interaction of multiple actors, modeling heterogeneous preferences of these actors towards SFM. In this context, the following are our premises. First, the proto-typical rational choice of the so called "Homo economicus" or the "rational economic man" (Pareto 1906), also termed "Chicago man" (McFadden 1999; Kant 2005) and who is implied in the Faustmann land rent theory, is difficult or impossible to specify. Rather, we anticipate that multiple levels of the system, not only the individual, are optimizing. The anticipated multiple levels of optimization include individual actors and coalitions of actors within their formal and informal forest-related organizations, namely stakeholder-groups and advocacy coalitions respectively (Kijazi 2007). By analogy, the individual is the result of lower level optimization at the atomic level, but the individual is a component of higher (elemental to compound) systems, e.g. stakeholder-groups, which are themselves optimizing, and competing for existence in the higher level. Second, consistent with rational-institutional choice rules (Ostrom 1990) we presume that organizations promote values and institutions which shape individuals preferences at this higher level of optimization. Third, we apply the principle of complementarity, as per Kant (2003a, b) and Khan (2005), by including variables in the matrix that would allow forest-actors to exercise both selfish and altruistic behaviours; economic and moral values; and to satisfy their lower level needs as well as higher level needs. Fourth, in the complex forest-actors-eco-system, all components including actors and their coalitions plus the eco-system are coevolving together—this is the higher cosmic-level optimization. Fifth, given the foregoing premise, borrowing from Colander (2005), even if one can specify what one means by rational choice non-contextually, the systemic forces rewarding "rational choice" are often weaker than they are in simple systems. Sixth, unlike in neo-classical economic theory, the analysis does not anticipate or project a predetermined equilibrium that must finally be reached if the system is left to its own devices. Rather, in the long-term, the complexity modeling is charted around the dynamic process through which one basin is reached temporarily, but other forces are building up to push it into another basin—akin to cosmic evolution. Seven, at a given time, then, sustainability means keeping within the existing, desirable basin of attraction, or moving into a more desirable one, but not going to another that is considered less desirable (Colander 2005; Musselwhite and Herath 2007).

In the context of the foregoing premises, the complexity modeling of the behaviors of forest stakeholders in Mount Kilimanjaro, Tanzania, include both their value (substantive) and institutional (procedural) preferences related to SFM. Specifically, we examine purposeful behaviors; informed self (or collective) choices and interests; and sustainability of the observed behaviors based on the stability of their current limit cycles. Stakeholders surveyed include forest authorities, park authorities, environmentalists, private estates and local communities. Then, we examine the role of formal and informal organizations, which create attractors that govern the dynamic choices/interests and interactions of stakeholders, specifically, the role of formal employment organizations (as stakeholder groups) and that of informal advocacy coalitions of individuals from different formal organizations but who share values, beliefs and purposeful activism towards SFM.

Next, in Sect. 3.2, we review the theoretical aspects of SFM, economic analysis, and complexity theory related to this study. In Sect. 3.3, we detail methodological aspects of empirical study. Results of the empirical study are presented in Sect. 3.4. The results are discussed in Sect. 3.5, followed by conclusions in Sect. 3.6.

3.2 Forest Sustainability, Economics, and Complexity

Sustainability has been embedded in forest economics for nearly last two hundred years, but the meaning of sustainability has evolved. Intellectual lineage of sustainability in forestry can be traced to the contributions of Pfeil (1822), Hundeshagen (1828), König (1864), Pressler (1860), but most particularly Faustmann (1849) illustrious soil expectation value formula. Mathematical optimization used to determine the best forest management solution, through determination of the land expectation value, corresponds with the principles of the neo-classical investment theory (Möhring 2001). However, as early as the 19th century, it was recognized that the land rent theory conflicted with the principle of maximum sustained yield timber management. By requiring reduction of usual rotations and stocking density and assuming that forestry investments start as an investment on bare land, the land rent theory also conflicted with the practical needs of foresters to manage the already existing forests using forester's rotation (Borggreve 1878; Möhring 2001). Regarding this tension, Möhring (2001) noted that Borggreve wrote: "The question is whether to liquidate the forests inventory or not…" (p. IX), and then he claimed "The forester's task in the first place is to maintain the forest and not to destroy or reduce it" (p. XI). The antithesis of the land rent theory, the so-called theory of the highest revenue that followed it was also criticized for focusing on the utility of wood production only, at the exclusion of non-timber forest products such as nature conservation, watershed protection, recreation, etc., which are also important to society (Möhring 2001). Thus, in Prussia, Hagen (1867) declared so-called 'golden words', which would not adhere to the principle of highest financial returns; rather, the state of Prussia was

'obligated to manage its forests to maintain an equal flow of multiple products for general welfare and future generations' (Möhring 2001).

The foregoing observations attest to the centuries-old-conflict between purely economic thinking vis-à-vis ecological limitations and social expectations. The conflict also indicates early recognitions of the over-simplifying nature of, albeit analytically elegant, economic models that are divorced from the complexity that exists in human and ecological systems. Yet, such neo-classical economic models founded on efficiency, control, and single equilibrium premises, have remained dominant in forest economics particularly under the sustained yield timber management era (SYTM) (Kant 2003a, b, 2005).

Forest valuation challenges in SFM have increasingly revealed that the SYTM-era models of forest valuation are incapable of delivering solutions useful to many forest economic decision problems under SFM (Kant and Lee 2004; Kangas et al. 2006; Kijazi and Kant 2010, 2011). This is particularly so because SFM has the goal of transforming forest management from SYTM to forest ecosystem management and from forest management by exclusion of user groups to management by inclusion of user groups (Kant and Lee 2004). Notably Forest economists have responded to SFM by the use of direct or indirect valuation techniques for non-marketed goods and services, so that these values can be made comparable with the values of traditional wood products (e.g. Lockwood et al. 1993; James 1994; Bateman and Lovett 2000; Bostedt and Mattsson 2006). However, numerous problems exist with the application of market-based methods for valuation of environmental attributes in general (Sen 1995) and forest valuation in particular (Kant 2003a, b; Kant and Lee 2004; Kijazi and Kant 2010, 2011). Primarily, the 'willingness to pay' foundation of these market-centered valuations does not provide room for all (economic and moral) socially defined forest attributes, or social states, to which individuals as citizens would attach importance, and which are critical for public discussions or decisions about SFM (Kant and Lee 2004; Kijazi and Kant 2010, 2011). These limitations are compounded by what Polanyi (1944, 2001) calls the fallacy of 'commodity fiction' of *laissez faire* economics, which when applied to nature and human societies results in drawing arbitrary boundaries around objects, thereby converting systems into disaggregated and discrete units, which are treated as separable without functional relationship between them. This ignores the complex interactions within human societies and between human societies and nature, which are critical for understanding economic foundations of SFM.

In responses to these limitations of neo-classical economic approaches, some economists have suggested the use of multiple criteria decision analysis (Bare and Mendoza 1992; Gong 1992; Kangas 1993; Liu and Davis 1995) and social choice approaches (Kant and Lee 2004; Kangas et al. 2006; Kijazi and Kant 2010) to SFM. Additionally, contributions from the other so called 'heterodox economics', including post-Keynesian economics, evolutionary economics, ecological economics, behavioral economics, experimental economics, and agent-based modeling (Kant and Berry 2005) are also very useful for economic analysis of SFM. Colander (2005) provided a strong theoretical justification for the use of

complexity theory to analyze such complex matrix of SFM. This study is an empirical investigation in this direction.

In the context of sustainable development, SFM means managing forests to meet the needs of the present without compromising the ability of future generations to meet their own needs. Economically, this demands elements of altruistic and cooperative behavior among social agents in contrast to the self-interest-maximizing rational agent of neo-classical economics guided by the "either-or" principle (Kant 2003a). Thus, in this study, in the context of "both-and" principle (Kant 2005), we use complexity theory model to capture dualistic nature of individual's behavior; i.e. both individualistic as well as altruistic and/or commitment orientations related to SFM values and institutions. Also, we discuss the results of our analysis on the basis of Kant's (2003a) proposed four sub-principles of SFM economics: existence, relativity, uncertainty, and complementarity, alongside premises of the complexity theory. This integration is supported by Kant (2005) observation that the complexity story of sustainability (Colander 2005) is consistent with Kant (2003a, 2005) economic principles of SFM. To achieve this integration, we place the two frameworks within a higher unifying 'principle of interdependence', which we believe is implied in both. Colander identifies the economics of SFM as part of a broader trend within economics, that he defines as a switching from the efficiency and control story to the complexity and muddling through story. The latter is a dynamic and evolutionary story, not characterized by a single equilibrium, but by basins of attractions. Sustainability, then, means remaining either in the existing basin of attraction or going to a more desirable basin but avoiding less desirable basins (Colander 2005). In this study, through the use of iconographic mapping, a common tool in complexity analysis, we examine basins of attraction that govern evolution of preferences of forest-agents in Mount Kilimanjaro towards SFM.

3.2.1 Analyzing Chaos in Complex Systems

Whereas analyzing complexity in economics of SFM is in infancy, major advancements in complexity theory have occurred in other fields, from which this review and subsequent analysis borrow. Our analysis, however, is limited to one branch of complexity theory, termed "chaos theory". Chaos theory describes the long-term behavior of a non-linear and dynamic system characterized by a great deal of irregularity at the micro-level but rather deterministic regularity at the macro-level (Kiel and Elliott 1996; Staveren 1999). Chaos theory is used to show such pattern of relationship between variables in a non-stochastic fashion (ibid.). There are three basic phenomenon associated with 'chaos': (1) the butterfly effect; (2) strange attractors; and (3) bifurcation. The butterfly effect associates chaotic systems with sensitivity to initial conditions, whereby, small variations of the initial condition may produce large variations in the long-term system behavior (Strogatz 2000; Devaney 2003). An attractor is an underlying order in a non-linear

system, where the mathematical points describing the system's behavior create pattern and structure (Kiel and Elliott 1996; Staveren 1999). Bifurcation is a process whereby the outcome splits into two; thus, linear continuity of nonlinear system's behavior is interrupted by dramatic change of relationship between variables (Gleick 1998). Our study is an examination of attractors or bifurcation patterns in a SFM value and institutional matrix, testing whether geometric representation of numerical data, describing the Kilimanjaro SFM regime, creates unique shapes of order relevant for SFM.

Specifically, our study examines presence of social-organizations, including SFM values and institutional variables, as basins of attraction, which govern stakeholder preferences and interests, or create bifurcation patterns that shape forest stakeholders' preferences in the dynamic social-ecological system. This is achieved through geometric representation of numeric data representing stakeholders' value and institutional preferences; then, by examining how the current patterns of forest stakeholders' preferences have been influenced by institutional-historicity of stakeholders, as discussed next.

3.2.2 Complexity, Historicity and Spatial-Temporal Dynamism

Understanding a complex system requires understanding the historical processes and interactions that led to the development of consistent patterns of behavior across time. Organization of human societies reflects dominant societal, historically formed self-understandings, and organizations reproduce the beliefs, values and interests as well as institutional practices of the society in which they are embedded, and in so doing they help perpetuate them (Tsoukas 1998). Economically, this has been empirically supported in historical analysis of sustainability of forests and other common-pool resources (e.g. Ostrom 1990; Gibson and Koontz 1998; Ostrom et al. 2002) and in economic rationality of individuals in general (Sen 2002). In complexity analysis of social systems, if the main interest is to establish temporal pattern of behavior, quantitative recording of longitudinal data (time-series and panel data) are indispensable. For spatial analysis, though, even cross-sectional data, as presented in this analysis, is adequate. But such analysis must be viewed also in relation to temporal nature of historical data captured in a cross-sectional study. According to Grengesen and Sailer (1993), at the abstract level, complex/chaotic systems share three important properties: (1) The system's state vector z_t at time t—i.e. cross-sectional profile; (2) An embedded environment's state vector $u_{t;}$ (3) The state of the system at time $t + 1$ is a function of the system state z_t and the environment state u_t at time t. Given that time and space are central aspects of chaos analysis, some social studies have applied time-series data (e.g. Frank and Stengos 1988; Combs et al. 1994). However, whereas limit cycles in chaos analysis typically report the evolving dynamic response of a system over time, they are not limited to time-dependent responses (Priesmeyer 1992). Hence, using cross-sectional data, as we do in this study, time could be replaced by profile

of respondent attributes in a three-dimensional geometric depiction of system dynamics: the first two depicting observed behavior as influenced by the third dimension, which represents respondent attributes (Dent 1994). An important aspect of complexity, however, remains valid: a given variable (or variables) affect (s) another (or others) in a non-linear, discontinuous, or even circular fashion. The influential variables are also affected by the dependent variable due to feedback between variables.

This leads to a question that can the role of time be totally dispensed of? To answer this, two other central questions need answering: does time, t, (above) represent an instant or duration? What role does t, per se, play apart from the state vector z_t and its environmental state vector u_t? Kijazi (2007) illustrated that time, t, alone, has no role independent of the system's state vector z_t and its environmental state vector u_t. Hence, it is more meaningful to speak of spatial–temporal influences as one unified aspect of reality, where time is only one dimension of space. Then, within a given space–time environment, the time t required to shape system behavior at $t + 1$ will depend on the context of state vector z_t of the system and its environmental state vector u_t. For example, in making leavened dough, an instant yeasting at time t (in seconds), is sufficient to influence the evolution and the state of the dough at any time $t + 1$. In contrast, the time, t, for the formation of dominant human choices and interests (e.g. related to SFM in this study) in a given society, is likely to be a duration, possibly many years required to establish institutions and social norms and values that shape these choices and interests, by experiences and feedbacks; in this case time, t, represent a duration (or history) rather than an instant. Such duration of experiences and feedbacks defines the underlying historicity.

In this study, therefore, as a time-modulator variable we use historicity of forest actors; i.e. their historical profile of SFM related organizational affiliations and activism—which approximates their system state z_t and environmental state vector u_t. In one unified dimension. The latter is then related to current pattern of actors' SFM preferences (system behavior at time $t + 1$). By analogy, our analysis is akin to a physician who prescribes treatment by diagnosis of patient's current symptoms (systems behaviour) in the context of patient's historical profile of ailment (state and environmental vector). Moreover, we contend that such current preferences (i.e. system behavior at time $t + 1$)—corresponding with specific values and institutions—though recorded in cross-sectional data also have temporal basis. This can be understood in the context of the "associative memory" notion of "social cognition and attitude theory", where current cognitions and value judgments are results of cumulative experiences, which may be activated on presentation of specific information of stimuli (Eiser 1997). This relates also to Hopfield's (1982) views of content-addressable memory, which entails accessing an attitude from memory in response to some priming stimulus or contextual cue—that is, "calling it into conscious experience". So, an attitude or value judgment that is strongly reinforced or associated with contextual cues function as a powerful attractor (Eiser 1997). In this context, based on the content of the Tanzania SFM policy (GOT 1998, 2002) we prepared evaluative survey questions.

The questions were used as stimuli, or contextual cues, for eliciting SFM preferences of respondents/forest actors in Kilimanjaro. But such currently stated preferences, and their corresponding basins of attraction, have an underlying history. They have arisen overtime and in the given historical context, they tend to converge to the current state. In complexity theory language, our interest is to examine how sustainable (i.e. stable and/or desirable) or unsustainable (i.e. unstable and/or undesirable) their limit cycles are.

3.3 Empirical Investigation

3.3.1 The Study Area

Mount Kilimanjaro is located 300 km south of the equator, in Tanzania, and it is the highest mountain in Africa reaching 5,895 m above sea level at its highest point. Mt. Kilimanjaro is the oldest protected area in Africa by contemporary state law, and was first declared as a game reserve by the German colonial government in the early part of the 20th century. The area was further gazetted as a forest reserve in 1921. The area above the main forest line (2,700 m) was reclassified in 1973 by the Tanzanian Government to form a National Park, covering 75,353 ha, surrounded by a Forest Reserve of 107,828 ha. Mt. Kilimanjaro National Park was inscribed on the World Heritage list in 1987 (Lambrechts et al. 2002). The mountain is a source of diverse values including : (1) domestic and industrial water; (2) an estimated 2,500 plant species and 140 mammal species (Lambrechts et al. 2002); (3) recreation values for domestic and foreign recreationists (Loibooki Loibooki 2002); (4) timber, honey and other bee products, fuel wood, nuts, fruits, root crops, seeds, poles for construction etc. The main stakeholder groups include local communities, Non-governmental Organizations (NGOs), government agencies, private sectors, local and global conservation organizations and other user groups (MNRT 2003).

3.3.2 Analytical Framework

The empirical analysis uses three-dimensional iconographic plots to examine the system dynamics from survey responses relating to values and institutional aspects of SFM. Stakeholders' scores over values or institutional attributes of SFM are plotted as X and Y (first and second) dimensions, while respondent data describing his/her historical profile are used to replace the time modulator (third dimension). The profiling data in this research include formal (work-related) organizational affiliations and informal organizations (advocacy coalitions, which will be described shortly). Questions relating to respondent's preferences are weighted by

respondents on a five-point Likert scale (Likert 1932). The scale ranges from strongly disagree (−2) to strongly agree (+2) with the posed SFM value or institutional statement, where undecided/uncertain answers are given a value of zero. Each survey question is specifically delineated to provide a separate axis of the "phase space", in complexity theory language, providing four main basins of attraction corresponding with the four quadrants of two-dimension X–Y plot (two basins for positive scores and two basins for negative scores). But within each basin, there are low and higher planes of optimization corresponding with the stakeholders' scores (e.g. +0.5 and +1 are lower levels of optimization than +2 in, albeit, the same positive basin of attraction.)

We hypothesized that formal and informal organizations, including values and institutions they promote, are quite important modulators of individual and social behavior, hence individual and collective choices. Because values and institutions they promote bear a history/time dimension, formal and informal organizational profiles were used directly to replace the time modulator in their own right so as to show patterns of individual and collective choices as influenced by institutional arrangements that have unfolded in the course of history. In this case we can think of a scale (level) of belonging of a respondent to a particular profile of organizations/institutional-historicity. Two types of organizations are considered: formal employment/work organization and informal 'advocacy coalitions'. The latter is consistent with the notion and premises of the "advocacy coalition framework (ACF)" (Sabatier 1993; Elliot and Schlaepfer 2001). The ACF corresponds with the institutional rational choice (Ostrom 1990) on the notion that institutional rules affect individual behavior, including their choices. The ACF, however, views these rules as a result of strategies and activities of advocacy coalitions.

3.3.3 Questionnaire Surveys

The field micro-survey was conducted in March—April, 2005. Prior to questionnaire surveys, a combination of review of policy documents and formal interviews with key representatives of different stakeholder groups were done: the objective was to appraise history of policy and institutional arrangements governing the management of forest resources in Mount Kilimanjaro before and after official adoption of SFM policy (GOT 1998, 2002). Then, a total of 133 respondents were questionnaire-surveyed (see survey procedure, next section). The questionnaire was divided into two sections. The first section contains respondents' historical profile data used as time modulator replacement: (a) formal occupation/profession, and (b) informal organizational/institutional affiliations and activism within the last decade. The second section, which is intended to elicit stakeholder preferences, provides overall preference scales and relates these scales to preferences that are specific to SFM values (substantive outcomes) and institutional/procedural aspects of SFM prescribed by the Tanzanian forest policy (GOT 1998).

3.3.4 Sampling Procedure

The study used stratified and cluster sampling. The following steps were followed: (a) deliberate choice of strata based on an auxiliary variable "organizational affiliation", leading into local community stratum, NGOs stratum, entrepreneurs (coffee estate) stratum, environmental agencies stratum, park authority stratum, and forest authority stratum; (b) clustering, which involved semi-random selection (based on accessibility) of 'representative villages' among villages that constitute the 'local community' stratum; (c) choice of participants within a given strata or cluster, by systematic random sampling in order to ensure reliable inferences. The first sampling point (respondent) was randomly selected in the list of members of a stratum or cluster, e.g. a list of adult villagers (>18 years old) from village register, followed by selection of every next kth member from the first sampling point where k, the sampling interval, is calculated as: k = population of adult villagers registered (N)/sample size required per village (n). The similar approach was used for other stakeholder groups. Conservation NGO and coffee estate surveyed were those within, or in close proximity to, the sampling transect determined by selection of representative villages (as described above). Park and forest authorities were deliberately chosen by virtue of their active involvement in the management of Mount Kilimanjaro forests.

The 133 respondents were surveyed based on a trade-off between statistical reliability versus resource constraints for obtaining larger sample size in such remote areas. To determine the number of respondents required for each stakeholder group, the proportionate allocation criterion was used qualitatively for guidance where larger sampling fractions were allocated to the strata with larger proportion of the total population and vice versa. Hence largest number of respondents (about 70 %) was obtained from the local community. Of the remaining 30 %, the Forest authorities and NGOs were assigned the larger proportions: about 9 % each (the former due to high proportion of its agents involved in forest decisions, and the later due to expected high variance—as the NGOs were observed to have workers with diverse backgrounds varying from local to international representatives). The private estates and park authorities were assigned smallest proportions of the total sample (6 % each) due to their actual smallest numbers of agents involved in current forest management decision-making in practice. A list of sampled stakeholder groups and sampled members per stakeholder groups is provided in Table 3.1.

3.3.5 Profiling Questions

Formal occupational organizations considered were those directly relevant to this research including: (a) National Park; (b) Forest Agency; (c) Coffee Estate; (d) Conservation NGO; and (e) Local Agrarian Economy. Advocacy coalitions

Table 3.1 Stakeholders surveyed in Mount Kilimanjaro

Stakeholder group	Agencies	Sample size
Local community	*Villages:* Lyasongoro, Nanjara, Mbomai, Kikelelwa, Rongai, Kamwanga, Kitendeni, Irkaswa, Lerang'wa, Olmolog, Londross, Ngaronyi, Foo, Mweka	93
Environmental groups	Himo environmental management trust fund (HEM);community management of protected areas conservation project and; Mweka community-based environmental organization	12
Forest authorities	Catchment forest office headquarters, Dar es Salaam; South Kilimanjaro catchment forest office, Moshi; Kilimanjaro regional forest office, Moshi; Hai district forest office	12
Park authorities	Tanzania national parks (TANAPA), Arusha; Kilimanjaro national parks (KINAPA) headquarters, Marangu; KINAPA outposts—Mweka, Rongai, Ngaronyi	8
Private (coffee) estates	Tchibo estate, Simba farm, Mountainside farm	8
Total		133

were determined by clustering of individuals from diverse organizations based on shared activism as determined by structured and open-ended questions requiring respondents to express their past and current non-job activities related to environmental activism, social justice activism, and community development activism, including collaboration with organizations undertaking such activities, during the decade preceding the survey. An environmental activist coalition, for instance, consisted of individuals that, in their historical profile, have self proclaimed to be environmental activists and also indicated evidence of environmental activities such as engagement with local environmental committees, tree planting, environmental campaigning, etc. Nine such coalitions were determined: (a) environmental activist coalition—as just described; (b) environmentally oriented coalition—self proclaimed support for environmental issues but no further evidence of activism in the profile; (c) environmental/resource committee coalition—involved in local environmental and natural resource committee but neither self proclaimed to be environmental activist, nor evidenced so in personal profile; (d) social justice activist coalition—self proclamation and/or other evidence of social justice activities; (e) community development activist coalition—self proclamation and/or other evidence of community development activities; (f) estate-economy coalition—estate workers without off-job activism; (g) forestry coalition—forest workers without off-job activism; (h) park coalition—park workers without off-job activism; and (i) local community coalition—local community residents without activism outside regular agrarian activities. Such clustering indicated that the environmental, social justice and community development coalitions have members from park, forest, and environmental organizations and local agrarians, thus, confirming the validity of the advocacy coalition framework (*op cit*).

3.3.6 Stakeholder Preferences of Values and Institutions

The second section of the questionnaire had two sub-sections. The first sub-section consisted of questions about stakeholder preferences regarding utilization and conservation of forests on Mount Kilimanjaro, specifying proposed substantive outcomes of forest management interventions e.g. timber harvesting in plantation forests and native forests; personal welfare values, societal welfare values, bequest values, etc. Thus, this section also required preferences for a wide range of SFM propositions including both self-interest and economic versus altruistic and moral values. The second sub-section required respondents to express institutional preferences necessary for SFM. For this purpose we provide a mix of formal and informal, as well as endogenous and exogenous institutions considered necessary to achieve SFM. By formal institutions, we mean those prescribed by law, e.g. forest governance regimes currently prescribed by the national forest policy (GOT 1998) and the forest act (GOT 2002), viz., state-controlled centralized governance, collaborative (joint-management) regime, and community-based/participatory regime. Formal institutions also include such aspects as forest-related rights and obligations endowed or obligated upon different actors by law (e.g. rights of local communities to extract products from forest buffer zones, and obligations to manage such forests, etc.). Informal institutions include forest governance rules and norms not necessarily defined by official law, but considered necessary to achieve SFM—e.g. trust, social norms, and networks of communications between different actors. We define endogenous institutions as rules and norms that are endowed from (and operate) within an organization—e.g. trust, social norms and networks just described. On the other hand, we define exogenous institutions as those that have to be guaranteed or imposed by an external agent—e.g. actors rights defined by law, financial guarantees to manage forests provided by the state to agencies entrusted with/or obligated to manage forests. Thus, our two classifications—formal and informal, endogenous and exogenous—are not mutually exclusive as some variables may fit both classifications. But the inclusion of both provides a more comprehensive framework for analysis and interpretation of the results. A list of value and institutional variables presented to respondents is summarized in Table 3.2.

3.3.7 Data Analysis and Interpretation

A description of limit cycles and other terminology used is summarized in Table 3.3 to enhance readers' comprehension. The time modulator replacement, i.e. respondent historical profile question, including formal organizational affiliation or informal advocacy coalition, was charted as the independent variable (third dimension), with responses to institutional and substantive choices of stakeholders related to SFM (i.e. actors' preferences) as dependant variables (first and second

Table 3.2 Variables used in the analysis and their contextual descriptions

	Values	Descriptions
1	Logging native species	Logging high value native timber species is necessary for local, regional and national economic well-being
2	Logging plantation species	Logging industrial plantation species is necessary for local, regional and national economic well-being
3	Local community use values	Local community regulated access to subsistence uses of forests is necessary
4	Conservation values	Conservation of biodiversity and eco-system services e.g. hydrological/water catchment values are necessary
5	Cultural and heritage values	Forest values necessary for sustaining local to national culture, traditions and customs
6	Option values	Differed uses of forests for future needs of present generations are important for SFM
7	Bequest values	Forests bequeathed to future generations to meet their needs
8	Existence values	Forests left to exist for their own goodness irrespective of human use
9	Personal values	Forests are necessary for actor's personal and/or household welfare
10	Organizational values	Forests are necessary for actor's organization's welfare
11	Societal values	Forests are necessary for societal (regional and national) welfare
	Institutions	*Descriptions*
1	Trust, social norms and communication networks	Actor's organization/community has adequate informal institutional rules necessary to monitor and reward or sanction individual behavior towards SFM
2	SFM Commitments	Actor's organization SFM roles, duties, objectives and obligations are clear
3	Stewardship	Actor's organization is taking actions towards SFM
4	Legitimacy	Actor's organization has institutional, legal, and customary authority to influence SFM decisions
5	Capacity	Actor's organization has financial and physical infrastructure and capabilities to effect SFM
6	Rights	Forest-related rights of the actor are clearly defined
7	Participatory/community-based	Local communities and other local stakeholder should play a greater decision-making and implementation SFM role as custodians of forests
8	Collaborative/joint forest management	Need to engage multi-stakeholder collaboration coordinated by a central agency
9	Centralized state bureaucracy	Centralized decision-making and law enforcement by a central/state agency should continue

dimensions). For each stakeholder group or advocacy coalition, mean values were calculated for each response according to the response chosen in each segment of the time modulator replacement question. The minimum and maximum means

Table 3.3 The key chaos theory terminologies and metaphors used in the study

Attractor	An underlying pattern of behavior that exists because of the inherent structural characteristics
Bifurcation	A branch point causing a different level of complexity. At bifurcation points, the system may become more or less complex
Limit cycle	The plotting and connecting of sequential observations on a phase plane
Period	A measure of the complexity, or amount of chaos or order between certain variables
Period 1 limit cycle	The least degree of chaos. Both variables always move together in one direction
Period 2 limit cycle	When only two quadrants are visited out of every four data points
Period 4 limit cycle	When all four quadrants are cycled before a quadrant is revisited
Period 8 limit cycle	Any limit cycle which is more complex than period 4
Phase space	The phase space is used to map the coordinates of the variables defining the behavior of the system in a multi-dimensional plot

This usage is consonant with typical usage in chaos analysis in social sciences using analytical approaches similar to this study (See for example Priesmeyer 1992; Dent 1994; Musselwhite and Herath 2004)

possible are then −2 and +2, respectively, for any response, which corresponds with the highest level of preference (or highest plane of optimization) in any basin of attraction/quadrant. When plotted, the cross-axis is zero.

In the time variables of qualitative nature, e.g. organizational historicity, natural ordering of responses is non-existent. Thus, we resort to post-analysis ordering, following a simple rule of thumb: after analysis the responses are ordered in way that would obtain the most parsimonious limit cycle; the data is thus plotted starting with the coordinate with the smallest Cartesian/Euclidean distance to the cross-axis, (say a = x1, y1) following with the coordinate with the second smallest Cartesian distance to the cross-axis, (say b = x2, y2), and so on. In addition to providing a standard approach, this method has the additional benefit of plotting sequentially actor groups that are closer (in their preferences), hence aiding inter-group comparisons. The resulting iconographs display the limit cycles of the preferences to (substantive and institutional) components of SFM included in the survey. Interpretation of the results is based on the following levels of system behavior (as per Priesmeyer 1992; Musselwhite and Herath 2004, 2007): period 1, involving limit cycles in which dynamic movements oscillate in one basin of attraction (i.e. one quadrant) only; period 2, in which movements oscillate across two basins of attraction; period 4, in which all four basins/quadrants are visited and the pattern is repeated; and period 8, which plots three or more quadrants in chaotic non-deterministic patterns.

3.4 Results

Results of stakeholder groups' preferences of self-interest and economic versus altruistic and moral values are presented in Fig. 3.1. The stakeholder valuations follows a period 2 pattern, involving a limit cycles in which dynamic movements across stakeholder groups oscillate in two basins of attraction only. Notably, valuations of altruistic and moral values oscillate within only positive basin of attraction, indicating consensus in support of such values by stakeholders. In contrast, self-interest and economic values oscillate in both positive and negative basins of attraction, indicating some disagreements among stakeholders. Among altruistic and moral values, conservation of biodiversity and hydrological values, bequest values, and societal welfare values oscillate at high plane of the positive basin of attraction—indicating their perceived high significance among stakeholders. Existence values, on the other hand, oscillate in the lower plane of the positive basin of attraction. Among self-interest and economic values, sustaining cultural and heritage values, personal/household welfare, and future option values oscillate in higher plane of the positive basin of attraction. Current community extractive use values for subsistence needs oscillates in relatively lower plane,

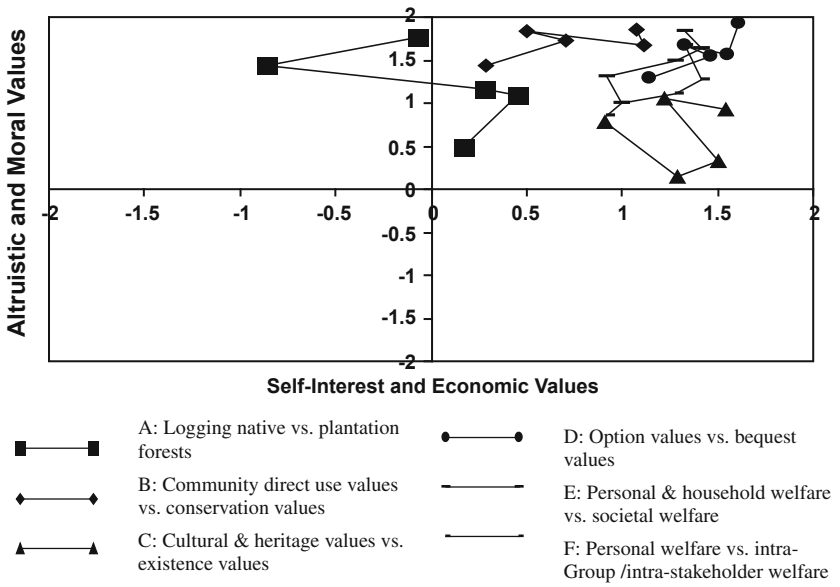

Fig. 3.1 Stakeholder groups' aspirational optimization of self-interest and economic versus altruistic and moral values. *Note* Point ordering of stakeholder values preferences: *A* estate, local community, ENGO, park authority, forestry authority; *B* park authority, local community, estate, ENGO, forestry authority; *C* local community, park authority, estate, ENGO, forestry authority; *D* park authority, local community, estate, ENGO, forestry authority; *E* park authority, forestry authority, ENGO, local community, estate; *F* forestry authority, park authority, ENGO, local community and estate

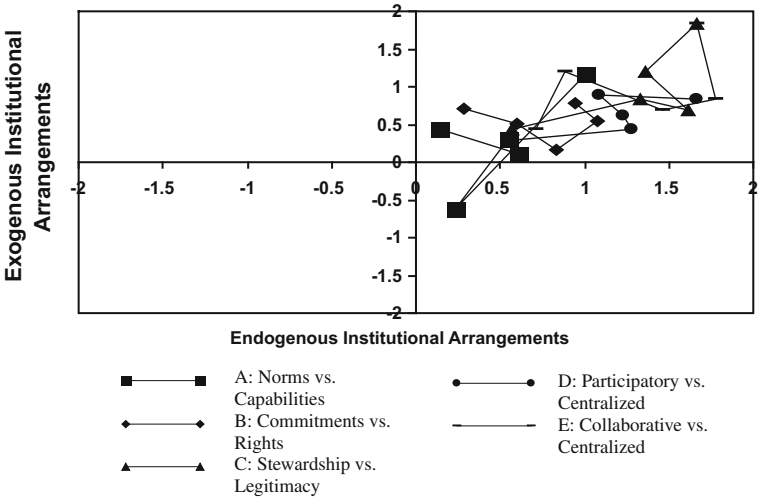

Fig. 3.2 Stakeholder groups' optimization of internal vs. external institutional arrangements. *Note* Point ordering of stakeholder values preferences: *A* park authority, ENGO, local community, forest authority, estate; *B* park authority, local community, estate, forest authority, ENGO; *C* park authority, ENGO, forest authority, local community, estate; *D* park authority, ENGO, forest authority, local community, estate; *E* park authority, local community, forest authority, ENGO, estate

albeit in a positive basin of attraction. Logging of high quality native timber species in natural forests oscillates between the lowest planes of positive basin of attraction and the negative basin of attraction—being a socially least desirable, and undesirable among some stakeholder groups—hence a socially divisive issue.

The results of stakeholder groups' preferences of formal and informal (as well as endogenous and exogenous) institutional arrangements are presented in Fig. 3.2. Generally, endogenous stakeholder institutional arrangement—involving self-endowments and capabilities of the stakeholder group or synergy with other stakeholder groups—oscillates in broader (low to high) planes of the positive basin of attraction. These are such aspects as social norms and networks of communication, SFM stewardship and commitments, as well as participatory and collaborative governance of forests.

Notably, among these, social norms, trust, and communication networks oscillate in the lowest plane of the positive basin of attraction, indicating stakeholder's low endowment of these attributes. On the other hand, the exogenous institutional arrangements—those involving endowments and capabilities that have to be guaranteed or enforced by an external agent/the state agency—oscillate mostly in lower planes of the positive basin of attraction, including a negative basin of attraction. These include stakeholder rights and legitimacy of claims and bureaucratic governance, plus financial and physical infrastructural capacity, which have to be guaranteed by a state-authority. Using a formal-informal dichotomy, it is also evident that formal institutions, such as state bureaucracy,

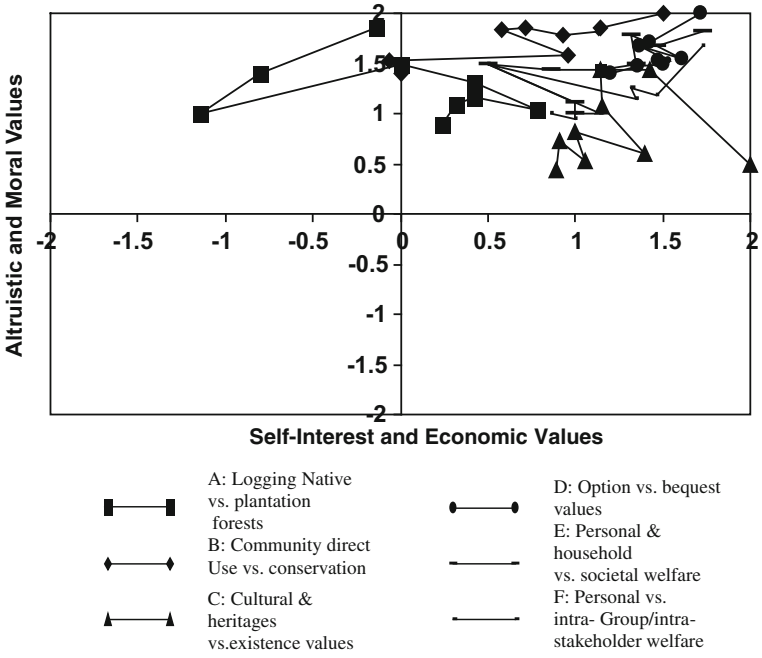

Fig. 3.3 Advocacy coalition groups' aspirational optimization of self-interest and economic versus altruistic and moral values. *Note* Point ordering of stakeholder values preferences: *A* social justice activist, local community, environmental committee, development activist, environmental-oriented, estate, environmental activist, park authority, forest authority; *B* environmental-oriented, forest authority, environmental committee, local community, development activist, park authority, estate, social justice activist, environmental activist; *C* park authority, estate, local community, forest authority, environmental-oriented, environmental committee, social justice activist, development activist, environmental activist; *D* environmental-oriented, park authority, environmental activist, local community, forest authority, estate, environmental committee, social justice activist, development activist; *E* environment-oriented, forest authority, environmental activist, development activist, social justice activist, environmental committee, local community, park authority, estate; *F* forest authority, social justice activist, park authority, environmental activist, environmental committee, development activist, local community

infrastructural and rights guarantees, oscillate in lower planes relative to informal institutions such as stakeholder commitments and stewardship. But as already observed, the latter are concurrently associated with low levels of trust, social norms, and communication network. Overall, the results show that preferences for institutional sustainability oscillate in lower planes.

Results of advocacy coalitions' preferences of self-interest and economic versus altruistic and moral values are presented in Fig. 3.3. The advocacy coalitions' preferences follows a period 2 pattern, involving a limit cycle in which movements oscillate in two basins of attraction/quadrants only. Like in the case of stakeholder-based preferences, preferences for altruistic and moral values oscillate within only positive basin of attraction. In contrast, self-interest and economic values oscillate

in both positive and negative basins of attraction. Similarly, the oscillations of specific values in the planes of basins of attraction are similar to those recorded in Fig. 3.1. However, analysis based on advocacy coalitions increases the planes of oscillation/optimization in the basins of attraction, particularly with respect to self-interest and economic values. One particular pattern that stands out is that the polarity engendered by logging of native forests vis-à-vis their conservation (and logging plantations instead) is intensified. Compared to stakeholder based preferences, advocacy coalitions' preferences have more extreme views held by the community-development-advocacy-coalition (in favor of logging native forests) versus those of environmental-activist-advocacy-coalition (disapproves logging of native forests). These extreme points oscillate in, respectively, positive and negative planes higher than those occupied by similar extreme points in stakeholder based analysis held by local agrarian community and park authority, respectively.

The results of advocacy coalitions' preferences of endogenous versus exogenous (and formal versus informal) institutional arrangements are presented in Fig. 3.4. Like in the case of stakeholder-based analysis, generally, endogenous stakeholder institutional arrangements oscillate in broader (low to high) planes of the positive basin of attraction. In contrast, the exogenous oscillate mostly in lower planes of the positive basin of attraction, including a negative basin of attraction. But there are remarkably different results. First, the preferences are of a relatively chaotic, period 8, involving a limit cycle in which dynamic movements oscillate in three basins of attraction/quadrants, including two negative basins. Of particular interest is the financial and physical infrastructural guarantees, of which six (out of nine) advocacy coalitions feel particularly deprived, four of whose preferences oscillate in the negative basins. One coalition occupies a negative basin both in-terms of infrastructure and social norms and networks.

3.5 Discussion of the Results

The oscillation of economic and moral values in the same positive basin of attractions (Figs. 3.1 and 3.3), is consistent with the "both-and" principle of SFM. The outcome represents the dualistic behavior of agents which include both individualistic as well as altruistic and/or commitment, as expounded by Kant (2003a). This dualistic behavior is exemplified in pair-wise comparison of such binaries as community use values/and conservation of biodiversity and hydrological values; cultural and heritage values and/existence values; option values and/bequest values; plus, personal and household welfare and/societal welfare. The results are, thus, consistent with the SFM sub-principle of complementarity, which suggests that human behavior may be selfish as well as altruistic, people can have economic values as well as moral values, and people need forests to satisfy their lower level needs as well as higher level needs (Kant 2003a, 2005; Khan 2005). Interestingly, altruistic, moral, and higher level values—particularly conservation of biodiversity and hydrological values, bequest values, and societal

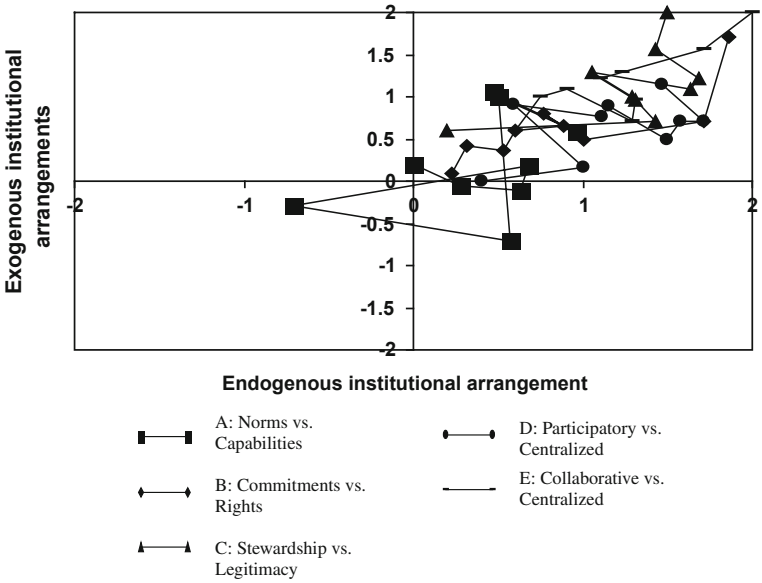

Fig. 3.4 Advocacy coalitions' institutional optimization of internal versus external institutional arrangements. *Note* Point ordering of stakeholder institutional preferences: *A* park authority, local community, environmental committee, development activist, environmental activist, forestry authority, estate, environmental-oriented, social justice activist; *B* local community, environmental committee, development activist, park authority, social justice activist, environmental-oriented, estate, forest authority, environmental activist; *C* park authority, environmental committee, local community, social justice activist, environmental-oriented, estate, forest authority, environmental activist, development activist; *D* park authority, forest authority, environmental-oriented, development activist, social justice activist, local community, environmental committee, environmental activist, estate; *E* park authority, development activist, local community, forest authority, environmental-oriented, environmental committee, social justice activist, environmental activist, estate

welfare—are of high relative significance (oscillate on higher planes of the positive basin of attraction) and least contentious. This complementarity is also applicable to endogenous and exogenous, as well as formal and informal institutions (Figs. 3.2 and 3.4). Interestingly, the states' bureaucratic (policing) approach, the dominant institutional paradigm preceding the SFM policy changes oscillates in lower planes of the positive basin of attraction relative to collaborative (joint forest management) and participatory (community-based) approaches introduced by the policy changes (i.e. GOT 1998, 2001). Evidently, the traditional approach is falling out of favor in the interest on multi-stakeholder engagement in SFM decisions and activities.

Study's results also correspond with other sub-principles of economics of SFM (Kant 2003a, b): namely existence, uncertainty, and relativity. The 'principle of existence' suggests that we cannot ignore the relevance of long surviving situations. Hence, we should focus first on achieving an economic understanding of the

existing human-forest interactive systems, in order to be able to predict whether the effects of proposed changes would be, on balance, positive or negative. Based on Kant (2003a) premise, and Khan (2005) re-interpretation, the principle can lead to at least two inferences from our results. First, we consider the existing basins of attraction ('existing conditions') so as to change them if so desired. E.g. the case of low levels of trust, social norms, and networks of communications among some stakeholders, and particularly deprivations of financial and other infrastructural capacity necessary to attain SFM as observed in Figs. 3.2 and 3.4. While the latter finding calls for state's guarantees of financial (and other) SFM infrastructure, we contend that such cost burden can also be reduced if trust, communication networks and social norms are improved. In dealing with dilemmas of collective action, social networks of communication are relatively more effective than centralized bureaucracies, which emphasize vertical authoritarian networks, in which the local agent is a subordinate to the superior government agent. For example, bureaucratic centralization of forest resources in Tanzania has encouraged considerable inefficiencies e.g. 'red tape' and 'rent seeking' behaviors, plus local defiance to conservation (MNRTE 1995; Kajembe and Ramadhani 1998; MNRT 2003). It has been argued that in solving dilemmas of collective action, vertical networks—those linking unequal agents of dissimilar status and power—are less helpful than horizontal networks, bridging together agents of equivalent status and power (Putman 1993). Horizontal networks build social capital, such as social trust and norms or reciprocity, which can be used to aid multi-stakeholder negotiation in SFM. Social capital is needed to: effect and sustain the change towards collective action; and lower the costs of devising and enforcing rules governing the use of the common pool resource (Ostrom 1998). In our results, the growing interest in decentralized governance (participatory and collaborative approaches) is a desirable early switch point towards SFM. Another desirable switch point is the presence of advocacy coalitions, which seems to operate alongside formal organizations, informally linking agents from different formal organizations, to optimize in more planes of the basins of attraction than formal organizations. Very likely, these net-works of decentralized and informal organizations may increasingly foster trust, networks of communication and social norms eroded by many years of top-down bureaucratic management of forests in Tanzania.

The second inference is that we examine the existing basins of attraction that are resistant to change, and their survival is rendered as an equilibrium that is not stable but desirable. E.g. the social polarization related to logging of high quality native species. Evidently, regarding this value, actors are 'optimizing' in low planes of the positive basin of attraction, or in a negative basin of attraction. This is completely counter to the logic of land rent theory (Faustmann 1849) or efficiency based models of neo-classical economics. Notably, the preferences in this study are consistent with current policy debates and public choices in Kilimanjaro, which are centered on curbing the problem of unsustainable logging of high value native timber species, and increased attention to interventions related to protection of biodiversity, hydrological and aesthetic values—and shifting timber production to industrial plantations (MNRT 2003). The later are typically managed on the

principle of maximum sustained yield (i.e. biological rotation). In native forests, timber is produced on neither economic rotation nor biological rotation, but sustenance of multiple values (timber, water, biodiversity, protection against erosion and landslides, tourism, etc.). Thus, even the observed negative optimization can be understood as a positive optimization of other desirable values, which are threatened by (i.e. compete with) timber extraction. Perhaps, the existence of this social polarization is helping against the extremes: i.e. liquidating forests through liberal markets, on the one hand, and strict preservation, on the other. The finding may fittingly correspond to Colander's (2005) remark: "in complexity story of sustainability, the resulting system is admired not for its efficiency, nor for any of its static properties; but for its very existence. Somehow the process of competition gets the piece of the economy together and prevents the economy from disintegrating. Observed existence, not deduced efficiency is the key to the complexity story line".

Interpreting the results in-terms of the existence principle also provide important insights regarding SFM by conservation vis-à-vis SFM by commercialization debate. Tanzanian forest and wildlife reserves are justified on registering tremendous economic and ecological benefits in aggregate values (CEDR 2001; MNRT 2003; UNEP 2001). Yet, regarding inter-stakeholder justice, many scholars suggest that such reserves often marginalize local communities, by curtailing their forest-dependent sources of livelihoods (Newmark 1993; Haule et. al. 2002; Goldman 2003; Kaltenborn et. al. 2005). This study's findings provide evidence that local resistance to conservation may not always be a result of the lack of conservation aptitude, but it may be due to contestation of existing conservation approaches or their distributional effects. This is further evidenced by the finding that current SFM commitments and stewardship (which oscillate in reasonably high planes of positive basins of attractions) (Figs. 3.2 and 3.4) are not supported with corresponding governmental guarantees in necessary finances and physical capacities, which oscillate in very low planes of positive basin of attraction for some actors and in negative basins of attraction for others.

The observed social polarization regarding logging native forests, can also find useful interpretation in the principal of uncertainty (Kant 2005). This principle suggests that due to uncertainties in natural and social systems, a social agent may typically not be in a position to maximize his outcomes, but will rather search for positive outcomes and learn by experience, such that resource allocation will be improved by adaptive efficiency, whose cumulated effects over time are likely to be more important than the achievement of efficiency at each point of time. This is akin to what Colander (2005) describes as complexity story of sustainability characterized by "reasonably bright individuals in an information poor environmental". Our analytical framework provides a scale of preferences with positive and negative scores with an uncertain (hesitation zone) in the middle. Presumably, this allowed individuals to factor-in uncertainty in their valuations. Where such uncertainty is perceived to be very high, reasonably, the stakeholder's optimize in the lower planes of the positive basin of attraction and in a negative basin of attraction close to zero (hesitation/uncertain zone)—e.g. regarding logging native

forests. That is, given widely perceived uncertainty regarding the impact of logging tropical-rain forests on other ecosystem values such as biodiversity and hydrological values—and perceived high importance of the latter—agents' preferences are ridden with caution. Such caution may also be a result of feedback from prior observed impacts of logging on other ecosystem values (problems of illegal logging of high quality native timber species in Kilimanjaro are well documented—e.g. Lambrechts et al. 2002). Analytically, the outcome is consistent with addressing the possibility (non-stochastic) uncertainty—i.e. uncertainty inherent in available information examined by Kijazi and Kant (2011). Operationally, this is consistent with the application of the precautionary principle; which is also consistent with fundamental uncertainty (Lavoie 2005). It means that the future is uncertain, not only because we lack the ability to predict it, which is tied to epistemological uncertainty and procedural rationality, but also because of the ontological uncertainty—the future itself is in the making and the decisions that we are able to take will modify its course (Rosser 2001; Lavoie 2005). Thus, Lavoie, argue that when agents take decisions that affect them directly, fundamental uncertainty leads them to adopt a course of action that will generate safety. In Kilimanjaro, presumably stakeholder want to generate safety with regard to ecological goods and services of forests such as water (for drinking, irrigation and hydro-power), subsistence needs, aesthetics, recreation and tourism, medicinal uses, etc., that are known to contribute greatly to the local, regional and national welfare. The same reasoning is applicable to the preferences for increased community access for current direct-use (extractive uses) of non-timber values, which though oscillates in a positive basin of attraction, in pair-wise comparison, it oscillates in a lower plane relative to its counter-part choice i.e. conservation of biodiversity and hydrological services.

All results considered together, adhere to Kant's (2003a, b) principle of relativity, which suggest that optimal solutions are not universal but rather situation specific; in many cases they will involve important non-market forces. The analysis is suitably encompassing in that it is contextual—the values and interests can be interpreted within a much broader framework of related to institutions, social well-being and social welfare, rather than the non-contextual Faustmann's land rent economics. Contextually, the results need to be interpreted in at least three frames of reference. First, Kilimanjaro forests are not private forests, but 'golden woods' of the nation by law, and different stakeholders entrusted with its management are obligated to manage its forests to maintain sustainable flow of multiple products for general welfare and future generations (MNRT 2003). Such obligations assume even high historical and contemporary significance given that Mount Kilimanjaro is the oldest protected area by contemporary state law in Africa, and is presently a world heritage site (Lambrecht et al. 2002). Second, the survey is based on the existing SFM policy (GOT 1998, 2001), and the results such as increased interest towards participatory and collaborative approaches to forest management are to be understood in the context of that policy. Third, the economy of communities on the slopes of Kilimanjaro is strongly inter-woven with the ecological goods and services from Mount Kilimanjaro forests (wood, water,

tourism, non-timber products, etc.). Also, the communities have centuries old history of managing and bequeathing natural resources: e.g. the traditional "Chagga-home-garden" agro-forestry systems (O'kting'ati 1984), government allocated half-mile strips of buffer zones of the natural forests (MNRT 2003), and traditional irrigation channels from Kilimanjaro forest water catchment (Gillingham 1999). We presume such experiences have also played a role in informing actors' forestry value and institutional understandings and valuations. Thus, SFM interventions, henceforth, can derive tremendous inputs from such experiences.

We think our results can be read better if the sub-principle of complementarity is also interpreted in relativistic sense. While our analysis and findings agree with Kant's (2003a, 2005) and Khan's (2005) "both-and" characterization of forest actors behavior, we think this characterization is complete only if viewed in a relativist sense in that an altruistic value at one level of optimization can become self-interest value at a higher level of optimization: e.g. at household level, optimizing with household rather than mere personal goals is altruistic; but this can conceivably become selfish, at community level, if it ignores broader community needs. Similarly, current non-use values such as option, bequest and existence values are all altruistic in essence. However, in relativistic sense, bequeathing is more altruistic in its equal consideration of future generations; while existence values are more so in their equal consideration of non-human species. E.g. our findings (Figs. 3.1 and 3.3) point out that inter-generational altruism (bequest) is more embedded in the culture than altruism to non-human species (existence). This outcome implies that SFM policies geared towards bequeathing forest to future human generation may receive little social resistance. But those geared only toward preserving other species for their own sake may require educational and/or public discussion programs to engender increased social sensitivities to such species.

Finally, while the result fit with sub-principles of SFM economics (complimentarity, existence, uncertainty, and relativity), we believe that in the context of complexity theory, they can be read better through a higher, unifying principle—The principle of interdependence; whereby all human and non-human components of eco-systems, including human economy, are recognized as inter-dependent actors and processes. Literature has indicated that most forest goods and services tend to have an inter-dependent (vis-à-vis perfect substitution) relationship with each other and/or with man-made capital (Costanza et al. 1997). Given value inter-dependence and externalities, market prices are only one category of scarcity signals; there are many social, cultural, and environmental signals of resource scarcity (Kant and Lee 2004, Kijazi and Kant 2010). The study's findings highlight the significance of these interdependences and presence of externalities and non-market scarcity signals in forest ecosystems. For example, in Kilimanjaro, currently high value native species—e.g. Camphor wood (*Ocotea usambarensis*), African Pencil Cedar (*Juniperus procera*) and Podo (*Podocarpus mylanjianus*)—are being illegally harvested due to high market demand (Lambrechts et al. 2002). Thus, the

negative oscillation of some stakeholder's scores of logging native timber species is a non-market 'social' signal of scarcity indicating perceived negative effect (externalities) of timber extraction on other values. Presence of several values in higher planes of the positive basin of attraction implies that such values are considered inter-dependent and complimentary in stakeholders' welfare space. In contrast to this interdependence/complementarity, the neo-classical economics notion of gross substitutability in allocation of natural capital assumes full commoditization of ecosystems by markets. But according to Kant (2003b), ecosystems cannot be sub-divided and commoditized and ecosystem capital satisfies differentiated needs, and, hence, gross substitution between different components of ecosystem capital or between ecosystem capital and man-made capital is not possible. Polanyi (1944, 2001) asserts that 'what we call land is an element of nature inextricably interwoven with man's institutions. To isolate it and form a market for it was perhaps the weirdest of all the undertakings of our ancestors.' Yet, the Faustmann forest land rent theory (op cit.) and its neo-classical economic derivatives are founded on isolating the forest land from human institutions and situating it in a liberal market economy under the neo-classical investment theory (Möhring 2001). Hence, complexity theory including market and non-market values plus market and non-market social institutions is more realistic in delivering SFM solutions than the land rent theory and neo-classical economics.

The complexity framework, based on our understanding of inter-dependence, is more likely to direct our attention from exclusive concern with economic efficiency, to address distributive, procedural, and ecosystem justice matters which may include the rights and interests of both human and non-human species. Consequently, the "both-and" and inter-dependence principles becomes the organizing principles of SFM through ecosystem sustainability, given that an ecosystem signifies a community of interdependent members. The members of an ecosystem include all those with dependency or legitimate interest in the functioning of the ecosystem. Viewing SFM through the lens of interdependent actors and processes working towards ecosystem sustainability—including complex interaction of nature, culture and ethics—draws attention to the question of legitimacy of claims that can be made on behalf of all the components of the ecosystem. This allows the appropriate accommodation or balancing of these claims. In essence, Figs. 3.1 and 3.3 depict a dynamic oscillation of such claims with respect to human values and ethics. Figures 3.2 and 3.4 depict claims related to institutions. Then, stability and/or desirability of basins of attraction of such claim, or otherwise, can guide sustainability interventions. In other words, to satisfy this more fundamental conception of SFM via ecosystem sustainability is to find an ethically acceptable relationship among all the competing and complementary interests of the members of the community. Normatively, the goal is to obtain a sustainable community in which the various interdependent components of the ecosystem (e.g. the natural ecosystem elements, social structures, and institutional structures) interact with each other in a way that contributes to the good of the others and to the good of the whole system.

3.6 Conclusions

The study has revealed early indicators of switch points both towards and away from sustainability. For example, the study reveals more stable limit cycles for values and less stable limit cycles for institutions. Hence, institutional interventions, rather than value sensitizations, may be more critical interventions for SFM in Kilimanjaro. The results also indicate desirability of increased forest actors' engagement through participatory and collaborative approaches—vis-à-vis the conventional top-down government bureaucratic interventions—as desirable switch points towards SFM. Additionally, the weights accorded to different values or institutional attributes by stakeholders can serve as early signals of the (positive and negative) distributional changes resulting from forest policies and management interventions currently in place related to these values and institutions. The observed complex interactions of forest actors (stakeholders and advocacy coalitions) and their heterogeneous and dynamic values and interests signify the need for reasoned and weighted evaluation of multiple values and interests in choosing our criterion and goals of sustainability. The results also imply that this can hardly be done through the representative behavior of the Homo economicus, and as a matter of intra and inter-generational justice and analytical realism, the evaluation should involve heterogeneous forest actors with stake in SFM system in question.

Our analysis has also demonstrated that complexity theory can deal with foundational limitations of neo-classical economics including Faustmann economics of land rent theory. Hence, in contrast to the more restrictive neo-classical economics, forest economists may find complexity theory to be a useful tool in the analysis of SFM alongside the so called 'heterodox economics' which have recognized complexity, multiplicity, dynamism and inter-relatedness of the real world. Forest economists have a challenge to continue to develop tools more suited for dealing with this complexity. Given advances in natural sciences such as physics and meteorology, and recent adoption of complexity models in management sciences, forest economists can learn and adapt conceptual models and analytical tools from these fields.

We believe our contribution in this regard is, but, a little step in the right direction towards a development of a more comprehensive complexity theory in SFM. We, nonetheless, acknowledge limitations endangered by the lack of time series data in this study. This has limited us to spatial limit cycles, and constrained us from analyzing temporal limit cycles of stakeholder behavior. Also for the same reason our analysis has been limited to geometric (iconographic) depiction of actor-system dynamics.

Finally, complexity based analysis can provide information more suited to economic and policy interventions in SFM because of the following reasons. First, in addition to quantitative results, it is capable of linking them with a descriptive profile of human systems and ecological systems including their parts and interactions. Second, it is holistic, comprehensive and trans-disciplinary. Third, it is based on actual preferences of real human beings rather than on the assumed

preferences of an imaginary super-rational representative agent. Fourth, it describes system dynamics and associated stability and feedback. Fifth, it describes social significance of diverse ecosystem and social values and their interrelations instead of using an arbitrarily single dimension market value. Sixth, it can look at different levels/scales of system structure and processes, and facilitates a flexible analytical and planning process. Seventh, it can implicitly incorporate ethics of quality of life, well-being, and ecosystem integrity. Eighth, it can specify required systemic limits to behaviors.

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