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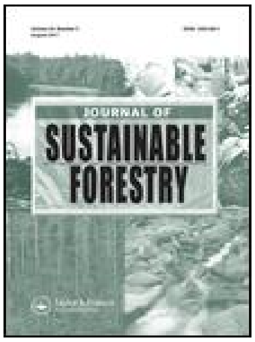

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A criteria and indicator prognosis for sustainable forest management assessments: Concepts and optional policy baskets for the high forest zone in Ghana

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ABSTRACT
This article establishes principles conveyed by criteria and indicators as a useful tool for measuring progress made toward sustainable forest management (SFM). Pedagogically, the conceptual construction raises questions on the following topics: (a) the various management practices and policies that exist in the high forest zone, (b) how criteria and indicators for assessments are selected, and (c) how progress made toward SFM is measured. Performance scores are established for indicators identified within the three sectors (forest ecosystems, forest communities, and the economy) for sustainability assessment. Measuring progress toward SFM operations are quantitatively performed with estimated maximum and minimum thresholds levels at which resource-use would be sustained using the Measure of Forest Resource-Use Sustainability Scale (MoFRUSS). The outcome of the measurement operations, as depicted by MoFRUSS, reveals the actual extent to which stakeholder's initiatives toward sustainable forest management has progressed and in which direction it is moving. It also offers optional policy baskets for resource management interventions from which the socio-eco economic bundle is recommended if the forestry sector of Ghana's Vision 2020 (sustainable development) is to be achieved with improved societal well-being, improved environmental health and vitality, and improved economic growth and development.

KEYWORDS
Criteria and indicators; Measure of Forest Resource-Use Sustainability Scale (MoFRUSS); performance scores; socio-eco economic bundle; sustainable forest management (SFM); Vision 2020

Introduction

The outcome of credible reports—including the Global Forest Resource Assessment (Food and Agriculture Organization of the United Nations [FAO], 2010a, 2010b), the International Tropical Timber Organization's (ITTO, 2010) report on tropical forest management, and the Millennium Ecosystem Assessment (FAO, 2010b; FC, 2013)—all indicate that global forest cover continues to dwindle at alarming rates, with the magnitude weighing more on tropical forests. However, with the inception of the criteria and indicator (C&I) initiatives, which departs from conventional forest management practices and focuses on resource-use in perpetuity (see Table 1) involving all relevant stakeholders,

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Table 1. Paradigm shift in conventional forest resource management.

Thematic category	Management objective	
	Conventional paradigm (sustained yield)	New paradigm shift (SFM)
Forest resources	• Specialized industry with limited products (timber)	• Open industry with multiple products and services
Resource managers	• Forestry authority • Limited other technical experts • Manage resources by themselves	• Forestry authority • Other technical experts • In partnership with socioeconomic practitioners, leaders in resource management, forest communities
Management system		
1. Publics	• Limited	• Plurality or unlimited
2. Problem	• Technical	• Technical and socioeconomic
3. Goal	• Sustained yield	• Equity and sustainability
4. Objective	• Limited	• Multiple
5. Strategy	• Conventional	• Diversified
6. Program	• Specialized	• Integrated
7. Administration	• Rigid hierarchical organized structure, centralized power, authority & decision-making. communication is one way	• Flexible open organized structure, developed power and authority, participatory decision-making, communication dual way
Forestry discipline	• Biological and physical sciences	• Biophysical and social sciences
Harvesting methods	• Use least cost regeneration techniques • Considered outside preview of forest managers	• Use techniques that maintain productivity of forest and by avoiding soil degradation and impoverishment of ecosystem • Considered within the preview of forest managers • Maintain wildlife populations and maintain species

Source: Based on Nunoo, 2010.

emerging progress on resource-use sustainability has been recorded (Moctar, 2005; Nunoo, 2007, 2010).

Trends in deforestation rates in Ghana from 1980–2014, as depicted by Table 2, indicate that until the middle of the 1990s marginal deforestation rates have been high and growing at *increasing rates*. This is attributed to a period in which Ghana focused on development, per the Bretton Woods financial institutions and the World Bank's directives, and thus exported more natural resources. This intervention was pursued without due regard to environmental

Table 2. Trend in deforestation rates in Ghana from 1980–2014.

	Period							
Deforestation rates (1,000/ha)	1980	1985	1990	1995	2000	2005	2010	2014
Absolute rates	60	86	120	135	138	135	135	135
Marginal rates	0	26	34	15	3	–23	0	0

Source: Based on FAO, 2010a; FC, 2014; FAO, 2014.

concerns (Nketiah et al., 2004; Nunoo, 2010). With a shift in management paradigm, however, from conventional practices (sustained yields) to sustainable forest management in the middle of the 1990s until 2000, marginal deforestation rates were contained. Although the rates themselves were still high they increased at decreasing rates. From 2005 until the present, marginal deforestation rates have been stabilized (Table 2) as a result of several interventions including the criteria and indicator interventions (Sheil et al., 2004).

Several sets of C&Is have been developed for the management of all type of forests (Table 3). Ghana has participated in a number of such processes, notably the International Tropical Timber Organization (ITTO) and the Africa Timber Organization's (ATO) initiatives, both involving some credible achievements (FAO, 2001; Nunoo, 2010).

With growing awareness of criteria and indicator assessments, the right to use forest resources in Ghana is now challenged by a high sense of eco-stewardship, not only to the appeasement of international organizations but also to meet specific targets for socio-economic growth and development initiatives as well as ensuring the well-being of fringe forest communities (Nunoo, 2010; Radulescu, 2009).

Table 3. Global criteria and indicator initiatives under four main thematic groupings.

	Main criteria and indicator initiatives and processes								
Criteria and indicators	ITTO	DZA	MP	TP	HP	LP	NEI	ADFI	ATO
Hierarchy									
Global level	No	No	No	Yes	No	Yes	No	No	No
National level	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Forest mgt. units	Yes	No	No	Yes	No	No	No	Yes	Yes
Thematic group									
A. Forest reserves									
Forest resource extent	Yes	Yes	—	—	Yes	No	Yes	Yes	Yes
Global carbon cycle	No	—	Yes	No	Yes	—	No	No	No
Ecosystem health, vitality	No	Yes	Yes	—	Yes	Yes	Yes	Yes	Yes
Biological vitality	—	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
B. Forest functions									
Productive	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Protective & environment	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
C. Development & social needs									
Socioeconomic needs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
D. Institutional framework									
Policy & legal framework	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Note. ITTO = International Tropical Timber Organization Initiative, DZA = Dry Zone Africa Initiative, MP = Montreal Process, TP =Tarapoto Proposal, HP = Helsinki Process, LP = Lapaterique Process, NEI = Near East Region Initiative, ADFI = Asian Dry Forest Initiative, ATO = African Timber Organization Process. Source: Based on FAO, 2001.

Sustainable forest management (SFM) is a management system that aims at maintaining critical forest ecological functions, biological diversity, and monitoring of anthropogenic activities with adverse environmental impacts so as to ensure forest resource availability for future use (Raison, Brown, & Flin, 2001; McCool & Stankey, 2001; Oliver, 2003).

This concept digresses completely from the principle of managing forest resources for *Sustained Yields* only. It is now pursued as part of satisfying obligations under the United Nations Framework Convention on Climate Change (UNFCCC) treaty postcommitments toward removal of carbon sinks (Raison et al., 2001). SFM is not only recognized by the United Nations Conference on Environment and Development (UNCED) as an important management strategy for achieving sustainable development objectives in developing countries with forest resources (ITTO, 2005), but it is also enshrined by UNCED under its forest policy provisions (FAO, 2001; UNCED, 1992), entreating all Governments to pursue the formulation of scientifically sound criteria and indicators for all forest types (McCool & Stankey, 2001).

Translating these ideas into measurable and achievable targets, this study affirms the underlying principles of the shift in paradigm (Table 2). It also subscribes to the numerous proliferation of conventions and treaties on biodiversity, resource conservation, and environmental care by which scientifically based and reliable data on the state of all types of forests could be generated (Ober, 1998).

The main goal of this article is to perform a prognosis via the assessment of progress made toward sustainable forest management over the last two decades and its implications for policy direction, climate change mitigation, and adaptation strategies in Ghana. Specifically, this research identifies and assesses appropriate criteria and indicators for forest resource-use in Ghana and performs a measure of success operations on progress made toward sustainable forest management over the last two decades.

Materials and methods study area

The high forest zone (HFZ) of Ghana lies between latitude 4° 30′ to 11° N and longitude 1° 10′ E to 3° 15′ W. It shares common borders in the east, west, and north with the republics of Togo, Cote d'Ivoire, and Burkina Faso, respectively. To the south of Ghana is the Gulf of Guinea. The forest is tropical in nature with three strata within the forest canopy (emergent, canopy, under canopy). This forest zone is peculiar for its high biodiversity, high precipitation (1,000–2,000 mm), and very warm average temperatures (27°C) throughout the year. A greater share of the resource's biogeographic affinity is that of Guinea-Congolian, which is confined to the southwestern part of the country. In the northern section of the country the forest type is Tropical Sudan, with the Dahomey-Gap running through the north to southeast. These prevailing ecological dynamics separate the major forest types in Ghana into six main researchable categories, including three classes of evergreen and three types of deciduous each with its distinct association of environmental conditions and plant communities.

The choice of study area is justified first by the fact that favorable conditions exist in Ghana for sustainable forest management assessments, as exemplified by a long history of forest management documents (see Tables 4a, 4b, and 4c). Second, a well-composed institutional and legal framework, backed by political will and good governance and being committed to sustainable resource-use, exists there. Third, the high forest zone,

Table 4a. Relevant policy documents for forest resource management in Ghana from 1906–1989.

Year	Policy/document	Main objectives
1906	Forestry sector legislation	■ Control harvesting of commercial tree species
1907	Timber protection ordinance	■ Diameter harvesting of commercial timber species
1908	Initial forestry sector survey	■ Functional unit responsible for policy implementation ■ Forestry department created ■ Forest reserves proposed
1927	First forest ordinance	■ Statute governing constitution and management of forest reserves ■ Consolidated power in central government to constitute and manage forest reserves.
1947	First national forest inventory	■ Document merchantable species ■ Covered 1,290 sq. miles of land
1948	First forest policy	■ 26 economic trees listed
1952	Follow-up of forest inventory	■ Planned management first introduced in forest reserves ■ Provided bases for management of resources with production and conservation objectives
1962	First concessions acts (Act 124)	■ Same objectives as 1947
1973	Follow-up forest inventory	■ First forest ordinance modified ■ Timber resources, concessions, forest reserves vested in the state in trust for owners ■ Power to grant concessions vested in sector minister
1974	Forest protection decree	■ Documented merchantable species
1985	Recent forest inventory	■ Certain activities within reserves prohibited ■ Resource user rights entirely transferred to state
1989	Forest resource management project (FRMP)	■ Estimate commercial log volume ■ 334 lesser known timber listed ■ Provide database for SFM ■ Assess biological productivity ■ Assess ecological status of forest ■ Provide information on nontimber products

Source: Based on Nunoo, 2010.

with a remaining total area of 1.6 million ha, is identified within the Biodiversity Hot Spots Zone in Africa, which is now of global concern (Ministry of Finance and Economic Planning [MF & EP], 2008; Ministry for Lands and Forestry [ML & F], 2005). This sector also serves as an important economic link in Ghana's quest for sustainable development (Vision 2020) in terms of employment, contribution to gross domestic product (GDP), foreign exchange earnings, and—most importantly—as a carbon sink (ITTO, 2005; MF & EP, 2008).

Theoretical construction

The theoretical construction of this article rests on Atkinson and colleague's (1997) sustainability framework of indicators, systems, innovation, and strategy (ISIS). The model, as depicted in Figure 1, rests on four premises/assumptions:

(1) Development, in whichever form it takes, has the tendency to erode environmental resources. Therefore, socioeconomic growth and development initiatives are inseparable from environmental issues (FAO, 2001).

Table 4b. Relevant policy documents for forest resource management in Ghana from1990–1999.

Year	Policy/document	Main objectives
1991	National environmental action plan & policy	■ Maintain ecosystem and ecological processes essential for the vitality of the biosphere ■ Ensure sound management of natural resources and the environment ■ Protect man, plants, and animals with respect to biodiversity conservation ■ Minimize pollution and public nuisance stemmed from development activities
1993	Environmental resource management program	■ Actual implementation program for the National Environmental Action Plan (NEAP) ■ Established the Environmental Protection Agency (EPA)
1994	Wildlife and forest policy	■ Conserve and protect forest and wildlife resources ■ Promote viable and efficient forest-based industries ■ Raise awareness of participatory resource management ■ Promote scientific-based management and utilization of forest and wildlife resources ■ Enhanced capacity building of national, regional, and district agencies for sustainable wildlife management
1996	Forest development master plan (1996–2020)	■ Aim to achieve sustainable development of forest and wildlife resources ■ Modernize the timber industry ■ Conserve biodiversity ■ Conserve the environment to be driven, to a larger extent, by the private sector
1997	Timber Resource Management Act (Act 547)	■ Promulgated to consolidate existing forest laws ■ Proposed stakeholders management of forest resources ■ Introduced Timber Utilization Contract (TUC) ■ Called for due diligence from stakeholders (EIA)
1998	Forest management certification system	■ Rolled out a computerized system for log tracking ■ Provide legal basis for financing the forestry department under the timber resource management regulation act (L.I. 1649/88)
1999	National land policy	■ Enacted to address fundamental problems associated with land management (wetlands, national parks, & reserves) ■ Initiated the Natural Resource Management Program (NRMP) to consolidate management of land, forest, and wildlife resources through collaborative management and to maximize returns of stakeholders input ■ Promulgated the forest commission Act No. 571/99 that established the forestry commission

Source: Based on Nunoo, 2010.

Table 4c. Relevant policy documents for forest resource management in Ghana from 2000–2014.

Year	Policy/document	Major objectives
2000	Pilot testing of principles, criteria and indicators	■ Adopted forest standards for SFM and Forest Certification by the Standards Boards ■ Develop Ghana Forest Management Certification Standards and Checklists
2001	National forestry development program	■ Ambitious tree planting exercise to be championed by the forest communities private entities/individuals, NGOs through agro-forestry and the Taungya system in degraded areas
2002	Forest Protection Act, 2002	■ Amended the Forest Protection Act to make punishment by forest offenders more deterrent ■ Made provisions for joint liability in prosecuting offenses
2003	Community forestry management project	■ Emphasized on community forest management of wildlife resources

Source: Based on Nunoo, 2010.

(2) Sustainable forest management is a pursuit of a particular equilibrium in a sustainability arena that combines improved societal well-being, improved economic growth and development, and improved environmental health and vitality indicators (Macgregor, 2000).
(3) Sustainability assessment is key to measuring progress toward achieving sustainable development goals, especially in developing countries with forest resources; positive indicators sustained over a period of time will establish the desired equilibrium (Bruyninckx, 2009).
(4) The further an equilibrium position is established away from the original position of the sustainability arena, the higher the level of well-being (Macgregor, 2000).

This article's theoretical construction (Equation 1) is that sustainable forest management (*SFM*) is a function (*f*) of increasing economic growth and development (Eco_{gd}), increasing environmental vitality (Env_{vt}), and increasing societal well-being (Sty_{wb}). The model is presented below as:

$$SFM = f(Eco_{gd} + Env_{vt} + Sty_{wb}). \quad (1)$$

A positive sign (+) indicates improvement in Well-being; as such, a negative sign (−) connotes otherwise. This function (Equation 1) represents an ideal situation, and thus it will be difficult to achieve this stable condition in the "real world." However, based on the Light Green Environmentalists' assertions (Bruyninckx, 2009; Gottlieb, 2001; Peterson del Mar, 2006), which are shared by the World Conservation Union (IUCN, 1999) and the World Bank (1994) on resource compensation, it is possible to improve well-being through selection of appropriate bundles of resource policy mix (Figure 1) if equilibrium is distorted.

In this sense, and all other things being equal, there will be no zero-sum trade-offs among the three sectors (environment, economy, community) (Macgregor, 2000) since sustainability can be restored through resource compensation along trade-off curves (see Figure 1). For instance, sustainability can be achieved on an indifference curve *x* (*Indif-sfm curve* ***x***) at point X on line OX (see Figure 1), with increasing improvements in economic growth and development (Eco_{gd}), increasing improvements in environmental health and vitality (Env_{vt}), and a decreasing societal well-being (Sty_{wb}) indicator as depicted by Equation 2:

$$SFM = f(Eco_{gd} + Env_{vt} - Sty_{wb}). \quad (2)$$

If the appropriate bundle of policies is applied then it will be feasible to use capital gains from the economic and environmental sectors to compensate societal well-being. Inferring from Figure 1, other equilibria situations are possible within the sustainability arena.

Application fields and usefulness of the model

This model is a transparent and robust system that could be used to test and compare different scenarios. It is an effective way of communicating measures of successes toward sustainable forest management among many stakeholders. As well, the approach allows for stakeholder participation. It also reduces value judgment and ensures equity of

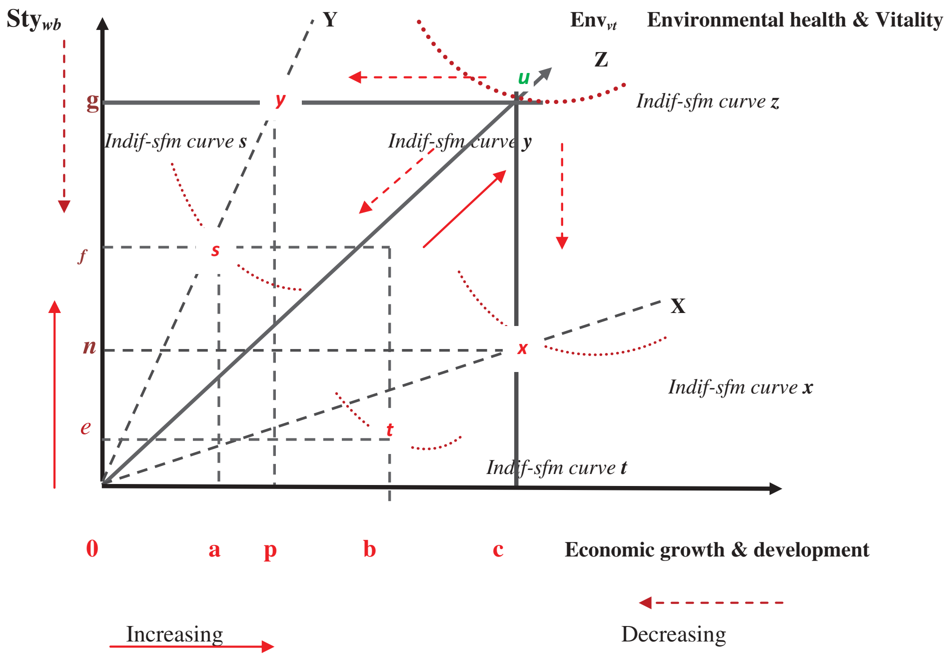


Figure 1. Equilibrium position in sustainability space.

knowledge between academicians, scientists, policy makers, and fringe forest communities (Henwood, 2001; ML & F, 2005; Morgan, 2006).

Using the Measure of Forest Resource-Use Sustainability Scale (MoFRUSS) will provide empirical bases for criteria and indicator development at the regional and national levels in order to evaluate progress toward sustainable development by tracking environmental progress and integrating them into sectorial policies (Cook & Laughlin, 1999; Wolfslehner & Hararld, 2008). In this way, the dynamics between environmental, societal, and economic policies would be more effectively identified and evaluated. This could be a test case for the Ministry of Environment and the Environmental Protection Agency of Ghana to implement the Environmental Pressure Indicators Programme and related sustainable development initiatives.

Subsequently, the model will be useful for policy formulation at interdepartmental government levels to integrate sustainable development initiatives in quantifiable terms and track progress over time at the national level. It will also aid in assessing the impacts of environmental degradation and climate change mitigation (Post-Kyoto protocol) programs. Moreover, since the model is based on self-regulation and negotiated agreements amongst target stakeholders, leaving it to local initiatives will produce proposals that could contribute to desired goals in addition to incorporating the polluter-pays principle and placing heavy reliance on economic instruments rather than the command-and-control regulations (Adriaanse, 1993; MESTI, 2005).

The model could also be applied as an educational tool in baseline environmental status assessments and as a measure of performance in delivering sustainability (Mendoza1 & Vanclay, 2008). The model makes it easy to combine indices that reflect environmental and social concerns not addressed in the standard procedure when assessing national accounting and the well-being of nations. Furthermore, it allows stakeholders to define their own localized sustainability threshold limits of significance and work towards the realization of such goals (Armstrong, 2008).

The Measure of Forest Resource-Use Sustainability Scale (MoFRUSS) will thus be useful to:

(1) research scientists and academicians researching into measures of successes toward sustainability issues;
(2) natural resource management teams tasked with improving on sustainable use of natural resources at the international, national, regional, and forest management units;
(3) interdepartmental government officials responsible for formulating sustainable policies pertaining to use of forest and other related resources;
(4) forest certifiers assessing timber companies' harvesting practices for certification purposes.

Nevertheless, the MoFRUSS has been contested on grounds of value judgment. Prescott (1999) and others (Anonymous, 1999), however, argue that in-spite of the role that computer-based modeling and multicriteria analysis continue to play in sustainability assessments, they are not necessarily always value-free because the uncertainty and risk potential in forestry makes almost every model/analytical result as value-based as much as it is scientific. The model is therefore a step ahead of conventional forest resources assessment methods.

Data analysis

The main sources of primary data were structured questionnaires, focus group discussions, and semi-structured interviews. Based on stratified and purposive sampling methods, this study took into consideration population dynamics of the six forest regions in the HFZ (Western = 100, Ashanti = 80, Brong Ahafo = 120, Central = 40, Eastern = 35, Volta = 25); the participants' level of knowledge on forest resource-use, deforestation rates, conservation practices; and administered questionnaires to fringe forest community households (n = 400), selected participants from the management of the Forestry Commission (n = 10), the Ministry of Environment, the Office of Science and Technology (n = 5), the Office of the Administrator of Stool Lands staff (n = 6), and from District Assembles (n = 6) between July 2014 and October 2014. Questions were asked to elicit for responses on resource-use sustainability and various conservation management practices/policies that exist in forest communities, as well as the methods of assessments over the past two decades. Data collected from group discussions and interviews (n = 80) were recorded and transcribed in the original language of the discussions and interviews. Local dialect (mostly Akan) to English translations were made by a university graduate from the School of Languages and verified by a professional translator fluent in the local dialect (Akan) and English. Additionally, a number of documents and materials were reviewed to provide secondary sources of data. Socioeconomic data analysis employed the Statistical Package for Social Sciences

(Version 17, SPSS Inc., Chicago, IL, USA), Microsoft Word (Windows 10, Microsoft Corp., Redmond, WA, USA), and Microsoft Excel to decode and process the original data.

Identification of criteria sets

A set of criteria was identified (Figure 2) to define the main aspects of sustainable forest management (SFM) to be assessed. The criterion selection was influenced by outcomes of various major global forest management processes, including the International Tropical Timber Organization (ITTO, 2005), Food and Agriculture Organization (FAO, 2005), United Nations Commission on Environment and Development (UNCED, 1992), and the World Bank's working documents on Criteria and Indicators (World Bank, 1994) as depicted by Table 3.

This selection allows for the comparison of outcomes with similar sustainable forest management initiatives in other forest ecological zones. Therefore, in line with meeting the Agenda 21 goals (Government of Ghana, 2003; Institute of Statistical, Social and Economic Research [ISSER], 2008; MF & EP, 2008), the criteria set identifies four thematic areas: Environmental health and vitality, Economic growth and development, Social well-being, and Enabling conditions. Eleven criteria sets were selected (Figure 2) for the study.

Identification and selection of indicator sets

An indicator is the quantifiable aspect of a criterion. Indicators were initially identified by a team of multicriteria and indicator experts (n = 5). These experts, together with stakeholders (n = 31), selected 61 measurable indicators across the thematic categories (Tables 5a, 5b, 5c, 5d, and 5e)—all of which were further verified by a team of experts (n = 3).

The availability of mechanisms and instruments for stakeholder indicator measurement were considered . Indicators that were field tested, cost effective, and possessed attributes perceived to be simple were rated as applicable. The measurement methodology included stakeholder participation and evaluation using an indicator applicability litmus scale (IALS) graduated from 0 to 100. Ratings are shown in Figure 3.

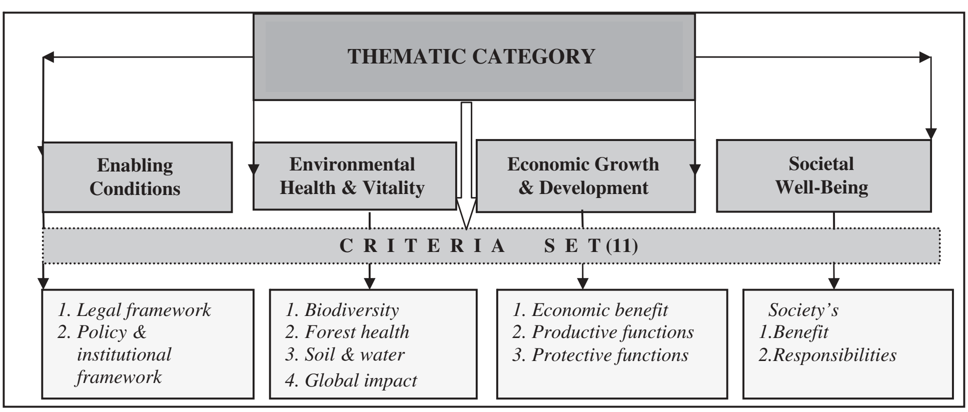


Figure 2. Criteria set for sustainable forest management in the high forest zone of Ghana.

Indicators that scored between 50 and 100 points were identified as applicable. Overall, 29 applicable indicators were adopted (see Table 6). Indicators that scored between 0 and 49 points were rated by stakeholders as not applicable and therefore not accepted for analysis.

Validating indicator applicability

A pairwise comparison (PC) method was used to validate the model in selecting indicator applicability. This method involves a one-on-one comparison between each of the applicable indicators (Brinker Fürnkranz, & Hüllermeier, 2006). An Expert Team is asked to make comparative judgments on the relative importance of each pair of indicators in terms of the criterion they measure. These judgments, according to Hüllermeier and Fürnkranz (2004) and Mendoza and Prabhu (1998), could also be used to assign relative weights to the indicators. The objective is to test for consistency (Landres, 1992) in selecting and ranking indicators by stakeholders as well as to minimize subjectivity.

In this scenario, consider a stakeholder team expert who will perform a pairwise comparison (PC) of indicators on a criterion (Environmental health and vitality), C.1.1, C.1.2, and C.1.3 from Table 5 (meaning criterion 1, indicator 1, criterion 1, indicator 2, and criterion 1 indicator 3, respectively). The expert reasons that indicator C.1.1 is more important than indicator C.1.2 and thus rates C.1.1 with a value of 5 higher than C.1.2. Because Indicator C.1.2 is also more important than indicator C.1.3 by a value of 5, the expert might conclude that indicator C.1.3 and indicator C.1.1 have equal importance. The expert's decision to give indicators C.1.1 and C.1.3 equal importance, however, is inconsistent. Given his previous comparisons (i.e., C.1.1 > C.1.2, C.1.2 > C.1.3), a logically consistent judgment would be to decide that indicator C.1.1 is more important than indicator C.1.3 by a value of 10.

Such inconsistencies cannot be ruled out, as according to Mendoza and Prabhu (1998) they may be attributed to oversights on the part of the team expert's interpretation of the indicators, fatigue, and/or the repetitive nature of the methodology involved. Therefore, a thorough exercise is required on the part of the experts, which again needs to be verified before indicators are deemed applicable. Guided by this sense of judgment, it is assumed that all indicators (Table 6) captured on the scale and finally accepted as *applicable* and *very applicable* for the research are logically representative.

Table 5a. Resource security indicators for sustainable forest management assessment.

Criteria	Element	Value	Indicators	Goal
Forest resource security	Resource base	Conservation and preservation of natural forest	Extent of area (ha) total land area under: 1. Natural forest 2. Plantation 3. Permanent forest estate 4. Comprehensive integrated land plans	SFM

Source: Field data, 2014.

Table 5b. Enabling condition indicators for sustainable forest management assessment.

Criteria	Element	Value	Indicators
Enabling conditions for SFM	Policy and legal frame- work	Forest production, forest conservation and protection	Degree (%) of 1. Land tenure and property rights relating to forests 2. Control over forest management, harvesting, and encroachment 3. Health and safety of forest workers 4. Local community participation
	Economic frame work	Existence of economic instruments to promote SFM & financial investment	Degree (%) of 5. Investment by the government 6. Domestic and private sources 7. International sources
	Institutional framework	Organized institutions, accountability, and public participation	8. Number and adequacy of institutions to support SFM 9. Adequacy of professionals and technicians to perform and support management, implementation, research and extension, 10. Existence and application of appropriate technology to practice SFM and for periodical monitoring and evaluation 11. Degree of public participation in forest management, 12. Access to information on forest policies, legislation and SFM practices

Source: Field data, 2014.

Performance scores

Performance scores are determined for each indicator (Table 7) by estimating maximum ($MaxT_l$) and minimum ($MinT_{lmt}$) threshold limits and the actual performance levels (AP_l) based on Prescott-Allen (1999) formulas for establishing indicator scores (Equations 3, 4, and 5):

(1) When an indicators' best performance is expressed by a maximum value and worse performance by a minimum value, Equation 3 is used to calculate the weighted index;

$$\left(\frac{AP_l - MinT_{lmt}}{MaxT_l - MinT_{lmt}}\right) \times 100. \tag{3}$$

(2) When an indicator's best performance is expressed by a minimum value and worse performance by a maximum value, Equation 4 is used to calculate the weighted index;

Table 5c. Economic growth and development indicators for sustainable forest management assessment.

Criteria	Element	Value	Indicators	Goal
Economic growth & development	Economic benefits	Sustained timber production	1. Timber harvesting levels 2. Total forest area available for commercial timber production 3. Mean annual timber increment 4. Volume of merchantable timber remaining on-site after harvesting 5. Extent of land tenure and property rights 6. Extent of financial commitment to SFM	Economic well-being
	Distribution of benefits	Forest industry & employment	7. Number of people employed in each forest-based activity 8. Related employment per unit volume of wood harvested 9. Value of paper and value-added manufacturing of timber per volume harvested 10. Number of timber trade related industries 11. Contribution of timber to Gross Domestic Product (GDP) 12. Number and adequacy of institutions to support SFM	
	Distribution of benefits	Recreation	13. Extent of ecoregions' conservation for recreational activities	
	Distribution of benefits	Forest products for domestic use	14. Extent of domestic wood demand by volume	

Source: Field data, 2014.

$$1 - \left(\frac{AP_l - MinT_{lmt}}{MaxT_l - MinT_{lmt}}\right) \times 100. \tag{4}$$

(3) When an indicator score signifies a deficit over actual performance levels, Equation 5 (top band of the scale and the base) is used to calculate the weight;

$$Topband - \left(\frac{AP_l - MinT_{lmt}}{MaxT_l - MinT_{lmt}}\right) \times base = \left[100 - \left(\frac{AP_l - MinT_{lmt}}{MaxT_l - MinT_{lmt}}\right)\right] \times 20. \tag{5}$$

Table 5d. Environmental health and vitality indicators for sustainable forest management assessment.

Criteria	Element(s)	Value	Indicators	Goal
Bio-diversity	a. Forest ecosystem diversity	a. Representative landscapes	1. Extent of ecoregions as a proportion of the high forest zone 2. Extent of area (ha) by forest type as a proportion of the high forest zone	
	b. Ecosystem diversity	b. Special places	3. Area (ha) of biologically unique protected or treated with special management provisions	Environmental health & vitality
	c. Species diversity	c. Wildlife habitat	4. Extent of area of habitat and population levels for known forest- dependent species at risk 5. Extent of area under natural forest	
Healthy forest	a. Incidence of disturbance & stress	a. Ecosystem health	6. Extent of forest area disturbed by logging, fire, insects, and diseases 7. Extent of area harvested using good tree technology	
	b. Ecosystem productivity	b. Natural productive capacity	8. Extent of mean annual increment (MAI), including planted area in the high forest zone 9. Extent of appropriate technology for timber harvesting 10. Extent of primary forest estate as a percentage of the high forest zone	
Soil and water	a. Ecosystem productivity	a. Surface water	11. Water quality standards 12. Flow rates of major rivers in the HFZ	
	b. Ecosystem productivity	b. Forest soils	13. Proportion of total productive forest area without measurable soil erosion & soil compaction due to forest operations	
Global impact	c. Climate change	a. Adopting to climate change	14. Net mass of carbon per unit area accumulated in the HFZ 15. Number of communication tools developed to explain climate change 16. Climate change strategies developed	
		b. Forestland conservation	17. Area (ha) of permanent forest depletion	

Source: Field data, 2014.

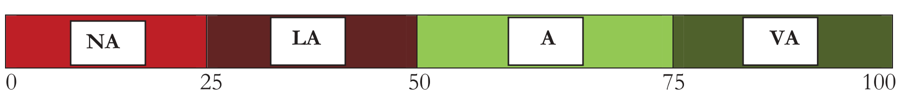
The variables are defined as follows:

- Actual performance level (AP_I): the performance level of the indicator observed or recorded over a cumulative period of not less than 10 yr. It paints a vivid picture of what is pertinent on-the-ground.

Table 5e. Environmental health and vitality indicators for sustainable forest management assessment.

Criteria	Element(s)	Value	Indicators	Goal
	Community involvement	Community perspectives and participation	1. Number of households in communities that have forest-based employment	
Societal well-being	Forest community well-being	Forest contribution to community's sustainability	2. Number of people that depend on the forest as their source of fuelwood 3. Number of households that use non-timber forest values 4. Adequacy of professionals to manage resources at fringes 5. Equitable sharing of forest proceeds 6. Employment in each forest-based activity	Societal well-being
	Fair decision-making	Fair and effective decision-making	7. Number of community participation processes used in preparing ecosystem-based forest management plans 8. Access to environmental education	
	Informed decision	Informed decision-making	9. Availability and accessibility of forest inventory information by the public 10. Research initiatives taken that will improve decision-making	
	Compliance to laws	Informed decision-making	11. Degree of compliance with eco-system-based forest management laws, regulations, and environmental protection plans	
	Community involvement	Community perspectives and participation	12. Degree of forest communities' participation in SFM 13. Number of households in communities that have forest-based employment 14. Control over management of forest resources 15. Extent of area under plantation	

Source: Field data, 2014.



NA= not applicable, LA = little applicability, A=applicable, VA = very applicable

Figure 3. Indicator application litmus scale.

- Minimum threshold limit ($MinT_{lmt}$): the level below which exploitation of the resource(s) will adversely impact the ecosystem over a cumulative period of not less than 10 yr. It is either a management or political target that is determined collectively by all management stakeholders.
- Maximum threshold level ($MaxT_l$): the desired target necessary to put the system into environmental sustainability equilibrium within the sustainability space. The maximum threshold level is also management or a political goal. Stakeholders of the resource determine it jointly.

Table 6. Applicable indicators for assessment in the high forest zone.

Environmental health & vitality indicators	Societal well-being	Economic growth & development
1. Extent of area by forest type as a proportion of the high forest zone	1. Number of households that depend on forest as sources of fuelwood	1. Contribution of timber to gross domestic product (GDP)
2. Extent of ecoregions as a proportion of the high forest zone	2. Number of households with forest-based employment	2. Forest area available for commercial timber production
3. Extent of area of habitat and population levels for known forest-dependent species at risk	3. Access to environmental education	3. Extent of ecoregions conserved for recreational activities
4. Extent of mean annual increment (MAI) including planted area in the high forest zone	4. Degree of forest communities' participation in sustainable forest management	4. Contribution to employment (households) levels
5. Area of forest disturbed by logging, fire, insects, and diseases	5. Equitable sharing of proceeds (stumpage)	5. Number of timber trade-related industries
6. Extent of area harvested using good tree technology	6. Extent of area under plantation	6. Extent of land tenure and property rights
7. Extent of primary forest estate as a percentage of the high forest zone	7. Employment in each forest-based activity	7. Number and adequacy of institutions to support sustainable forest management
8. Extent of appropriate technology for timber harvesting	8. Adequacy of professionals to manage resources	8. Extent of financial commitment to sustainable forest management
9. Extent of area under natural forest	9. Extent of area considered for special management provisions in the high forest zone	9. Extent of domestic wood demand by volume
10. Net mass of carbon per unit area accumulated in the high forest zone	10. Control over management of forest resources	—

Source: Field data, 2014.

- The actual performance level minus the minimum threshold limit ($AP_l - MinT_{lmt}$): the likely attainable goals given management budget constraints.
- The maximum threshold limit minus minimum threshold limit ($MaxT_l - MinT_{lmt}$): the likely un-attainable goals given management budget constraints.
- The top-band is the upper limit of the scale. On MoFRUSS it is equal to 100.
- The *base* is the lower limit of the scale. On MoFRUSS it is equal to 20.

Results and discussions

The weighted scores are modeled using the Measure of Forest Resource-Use Sustainability Scale (MoFRUSS). The scale is calibrated to determine the extent of progress toward SFM. MoFRUSS is a 0–100 end-point performance scale graduated into five bands of 20 points each on the "Y-axis" for measuring forest resource-use sustainability. The "X-axis" is represented by three sectors (ecosystem, society, economy). It is a modified version of the barometer of sustainability (BoS) developed by Robert Prescott-Allen for the Conservation International Union for assessing the well-being of nations (Anonymous, 1999; Prescott-Allen, 1999). The results are exhibited in Figure 4.

Table 7. Performance scores for applicable indicators.

Environmental health & vitality indicators	Societal well-being	Economic growth & development
1. Extent (ha) of area by forest type as a proportion of the high forest zone. *3 $AP_I = 1{,}578{,}990$, $M_{in}T_{Imt} = 0$, $MaxT_I = 8{,}525{,}000$ Source: Based on FAO, 2010b	1. Number of households that depend on forest as sources of fuelwood. *5 $AP_I = 60$, $M_{in}T_{Imt} = 10$, $MaxT_I = 30$ Source: Based on Ghana Statistical Service (GSS), 2010; FAO, 2010a	1. Contribution of timber to gross domestic product (GDP). *3 $AP_I = 3.5$, $M_{in}T_{Imt} = 0.2$, $MaxT_I = 5.4$ Source: Based on Field data, 2014; ML & NR, 2014a, 2014b; World Bank, 2004
2. Extent (ha) of ecoregions as proportion of the high forest zone. *3 $AP_I = 1{,}268{,}500$, $M_{in}T_{Imt} = 0$, $MaxT_I = 1{,}578{,}990$ Source: Based on FC, 2006; FAO, 2010b	2. Number of households with forest-based employment. *5 $AP_I = 53$, $M_{in}T_{Imt} = 15$, $MaxT_I = 35$ Source: Based on GSS, 2010; FAO, 2010a	2. Forest area available for commercial timber production. *3 $AP_I = 1{,}136{,}000$, $M_{in}T_{Imt} = 500{,}000$, $MaxT_I = 1{,}296{,}400$ Source: Based on Forestry Commission (FC), 2010a; Field data, 2014
3. Extent (ha) of area of habitat and population levels for known forest-dependent species at risk. *4 $AP_I = 140$, $M_{in}T_{Imt} = 0$, $MaxT_I = 4{,}703$ Source: Based on FAO, 2010b	3. Access to environmental education. *3 $AP_I = 53$, $M_{in}T_{Imt} = 0$, $MaxT_I = 87$ Source: Based on Field data, 2014; Kodum, 2013	3. Extent of ecoregions (km^2) conserved for recreational activities as a proportion of total forest. *3 $AP_I = 12{,}685$, $M_{in}T_{Imt} = 0$, $MaxT_I = 13{,}385$ Source: Based on FC, 2010b; Field data, 2014
4. Mean annual increment (MAI) including planted area (ha) in the high forest zone. *3 $AP_I = 4{,}650{,}000$, $M_{in}T_{Imt} = 2{,}513{,}754$ $MaxT_I = 6{,}000{,}000$ Source: Based on FC, 2006; FAO 2010	4. Degree of forest communities' participation in sustainable forest management. *3 $AP_I = 490{,}414$, $M_{in}T_{Imt} = 0$, $MaxT_I = 3{,}701{,}241$ Source: Based on Field data, 2014	4. Contribution to employment (households) levels as a proportion of employment in the forest zone. *3 $AP_I = 104{,}000$, $M_{in}T_{Imt} = 13{,}520$, $MaxT_I = 200{,}000$ Source: Based on GSS, 2010; Field data, 2014
5. Area (ha) of forest disturbed by logging, fire, insects, and diseases. *4 $AP_I = 75{,}000$, $M_{in}T_{Imt} = 22{,}000$, $MaxT_I = 100{,}000$ Source: Based on FC, 2006; FAO, 2010	5. Equitable sharing of proceeds (stumpage) as a percentage of total revenue. *3 $AP_I = 40.5$, $M_{in}T_{Imt} = 22.5$, $MaxT_I = 90$ Source: based on FC, 2010b; Tropenbos, 2010	5. Number of timber trade-related industries. *4 $AP_I = 411$, $M_{in}T_{Imt} = 350$, $MaxT_I = 400$ Source: Based on FC, 2015; Field data, 2014; Sackey, 2007
6. Extent of area (ha) harvested using good tree technology. *3 $AP_I = 762{,}400$, $M_{in}T_{Imt} = 374{,}400$, $MaxT_I = 1{,}136{,}400$ Source: Based on FAO, 2014	6. Extent of area under plantation. *3 $AP_I = 400{,}000$, $M_{in}T_{Imt} = 0$, $MaxT_I = 2{,}000{,}000$ Source: Based on FC, 2006; Field data, 2014	6. Extent of land tenure and property rights as a percentage of total revenue.*4 $AP_I = 55$, $M_{in}T_{Imt} = 28$, $MaxT_I = 83$ Source: Based on FC, 2010b; Field data, 2014; ISSER, 2008.

(*Continued*)

Table 7. (Continued).

Environmental health & vitality indicators	Societal well-being	Economic growth & development
7. Extent of primary forest estate (ha) as a percentage of the high forest zone. *3 AP_I = 352,500, $M_{in}T_{lmt}$ = 0, $MaxT_I$ = 1,634,100 Source: Based on FAO, 2014, FC, 2006	7. Number of people employed in each forest-based activity. *3 AP_I = 3,150,000 $M_{in}T_{lmt}$ = 3,000,000 $MaxT_I$ = 4,150,058 Source: Based on Field data, 2014; FC, 2006; GSS, 2010	7. Number and adequacy of institutions to support sustainable forest management. *3 AP_I = 55 $M_{in}T_{lmt}$ = 28, $MaxT_I$ = 83 Source: Based on FC, 2010b; Field data, 2014; FAO, 2005; Birikorang & Rhein, 2005
8. Extent of appropriate technology for timber harvesting. *3 AP_I = 3, $M_{in}T_{lmt}$ = 0, $MaxT_I$ = 7 Source: Based on Cagliostro, 2005; FAO, 2014	8. Adequacy of professionals to manage forest resources. *3 AP_I = 8,202, $M_{in}T_{lmt}$ = 5,000, $MaxT_I$ = 10,520 Source: based on FC, 2006; Field data, 2014	8. Extent of financial commitment ($) to sustainable forest management. *3 AP_I = 1,939,600,000 $M_{in}T_{lmt}$ = 2,200,000,000, $MaxT_I$ = 5,000,000,000 Source: based on FC, 2010; Field data, 2014; MLF, 2010; World Bank, 2008
9. Extent (ha) of area under natural forest.*3 AP_I = 1,634,000 $M_{in}T_{lmt}$ = 1,300,000 $MaxT_I$ = 8,525,063 Source: Based on FAO, 2014, FC, 2006	9. Extent of area considered for special management provisions in the high forest zone. *4 AP_I = 117,322, $M_{in}T_{lmt}$ = 43,400, $MaxT_I$ = 357,800 Source: based on FC, 2006; Field data 2014; World Bank, 2006	9. Extent of domestic wood demand by volume. *4 AP_I = 1,563,000 $M_{in}T_{lmt}$ = 946,000, $MaxT_I$ = 1,200,000 Source: Based on FC, 2006; Field data 2014; ITTO, 2010
10. Net mass of carbon (metric tonnes of carbon) per unit area accumulated in the high forest zone. *3 AP_I = 415, $M_{in}T_{lmt}$ = 233, $MaxT_I$ = 649 Source: Based on FAO, 2014; Houghton, 2003, IPCC, 2006	10. Control over management of forest resources as a percentage of proceeds disbusement. *3 AP_I = 79.8, $M_{in}T_{lmt}$ = 0, $MaxT_I$ = 100 Source: Based on FC, 2006; Field data 2014; World Bank, 2006	—

Note. *3—Equation 3 is used to calculate performance score and indicator position on the scale.
*4—Equation 4 is used to calculate performance score and indicator position on the scale.
*5—Equation 5 is used to calculate performance score and indicator position on the scale.

According to the prognosis, environmental health and vitality (Env_{vt}) indicators did not performed well. With a mean score of 454 and a weighted index of 45.4 (see Table 7), it registered its performance within the transitional zone segment of the measure of forest resource use sustainability (see Figure 4). Comparatively, societal well-being (Sty_{wb}) indicators performed even worse than environmental health and vitality indicators. A critical look at the figures in Table 7 shows a much greater improvement in individual score points in Env_{vt} indicators than societal well-being. The later indicators (Sty_{wb}) accumulate a total of 411 points (Table 7) with a weighted index of 41.1, which also registered within the lower limits of the transitional zone (Figure 4).

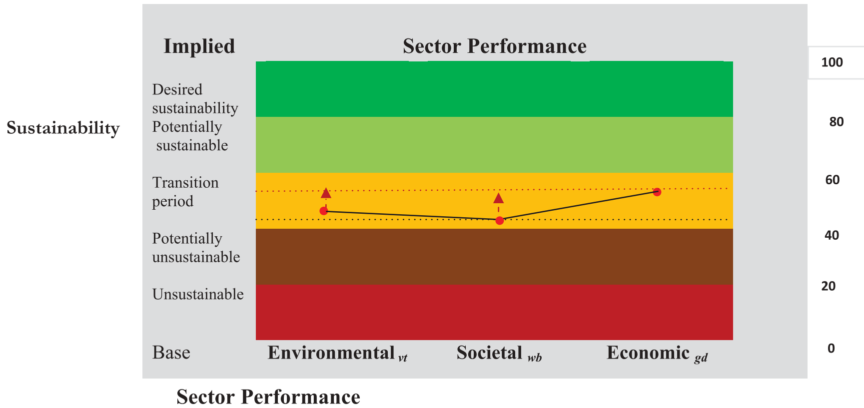


Figure 4. The Measure of Forest Resource-Use Sustainability Scale (MoFRUSS), showing extent of progress toward sustainability.

Economic growth and development indicators (Eco_{gd}), however, performed much better than the aforementioned indicators. With a total score of 493 points and a weighted index of 54.8, it registers an impressive position within the upper limits of the transitional zone on the scale. Much improvement in the economic growth and development indicators, perhaps, supports arguments made earlier that until the mid-1990s, forest management policies were all economic centered and directed at increased sustained yields.

It is therefore evident from MoFRUSS (Figure 4) that, cumulatively, measures of successes toward sustainable forest management in Ghana over the last 2 decades have not achieved their desired sustainability. However, these measures did fall within the transitional period (the mid-sections) of the scale.

The transitional zone, once reached, represents a critical platform for stakeholders to either concretize efforts made (*launch into the potentially sustainable zone*) to attain a desired sustainable status or to negate all efforts (*fall back in the potentially unsustainable zone*) achieved. From the conceptual model, a new equilibrium position will be established in the sustainability arena if the three sector (ecosystem, society, economy) indicators perform well (positive) or have the tendency to rise through resource substitution (Dasgupta, Susmita, Benoit, Hua, & Wheeler, 2005). According to MoFRUSS, such compensations can be made from gains already experienced in the economic sector to that of the ecosystem and society.

The model (Figure 1) postulates seven bundles of policy baskets (Table 3d) for decision makers. With this level of sustainability, as revealed by the prognosis, the appropriate policy intervention for the forest zone is to draw on policy basket 6, which has *ecosystem* and *societal well-being* as the policy direction to restore equilibrium (*Societal Well-being and Ecosystem health and vitality indicators*). Economic resources amassed over the years should be used to compensate society and ecosystem health and vitality. This policy intervention will encourage forest communities to maximize resource-use to improve standards of living and promotes awareness of the forest ecosystem‘s ability to sustain itself over the next reasonable period of time through collaborative efforts. An opportunity for improvement associated with the outcome of the research, which policymakers could explore further in order to effectively achieve the stated objectives mentioned above, is embedded in the concept of reducing emissions from deforestation and forest degradation (REDD Plus). This opportunity could translate to monetary gains for farmers who consciously make attempts to increase forest cover and minimize land degradation (Mandal & Joshi, 2015).

Conclusion

This article agrees with the precepts of sustainable forest management (SFM): that sustainable forestry is an important management strategy, which if effectively pursued and monitored could sustain the forest sector. According to the research, it is evident that desired sustainability has not been achieved. Ghana's effort toward sustainability appears to be in transition, signifying disequilibrium and the need to pursue a socio-eco-economic policy mix to restore equilibrium.

For this intervention to work, gains made in the economic sector will be need to compensate ecosystem and fringe forest communities. Furthermore, progress toward sustainable forest management is closely linked with reducing emissions from deforestation and forest degradation (REDD Plus), and as such this progress carries promising prospects. Pragmatic SFM practices could minimize deforestation rates and annual timber yields through afforestation, the implementation and enforcement of harvesting standards, and the setting of sustainable thresholds levels.

These recommendations could safeguard biodiversity and preserve other ecosystem services through a community-participatory approach, with the potential to mobilize financial support and other needed logistics to fringe forest communities as a means to diversify subsistence ways of living. Lastly, these interventions could also support a legal basis for tropical countries with forest resources to make claims for carbon financing under the post-Kyoto protocol initiatives to fight climate change a relatively lower cost.

References

Adriaanse, A. (1993). *Physical planning and environment: Essential environmental information*. The Hague, The Netherlands: The Netherlands Ministry of Housing.

Anonymous. (1999). *Assessing progress toward sustainability: The system assessment method illustrated by the wellbeing of nations*. Cambridge, UK: IUCN.

Armstrong, A. T. (2008). *Gold strike in the breadbasket: Indigenous livelihoods, the World Bank, and territorial restructuring in western Ghana* (First Development Report No. 18). Washington, DC: Institute for Food and Development Policy.

Atkinson, G., Dubourg, R., Hamilton, K., Munasinghe, M., Pearce, D., Yong, C., … & Hansen, H. G. P. (1997). *Measuring sustainable development: Macroeconomics and the environment*. Cheltenham: Edward Elgar Publishing Limited.

Birikorang, G., & Rhein, M. (2005, March). *Reforming Ghana's forest fiscal regime* (Draft Status Report, Forest Sector Development Project). Accra, Ghana: Forestry Commission.

Brinker, K., Fürnkranz, J., & Hüllermeier, E. (2006). *A unified model for multilabel classification and ranking*. Retrieved from https://www.ke.tu-darmstadt.de/~juffi/publications/ecai-06.pdf

Bruyninckx, H. (2009). Environmental evaluation practices and the issue of scale. *New Directions for Evaluation*, *122*, 31–39. doi:10.1002/ev.293

Cagliostro. (2005). Inter-criteria and indicators process collaboration workshop. A collaborative effort by the International Tropical Timber Organisation (ITTO), the ministrial Conference on the protection of Forests in Europe (MCPPE), the Montreal Process, the Food and Agricultural

Organisation (FAO) of the UN, the UN Economic Commission for Europe (UNECE) and the U. S. Forest Services. Biolowieza, Poland 25–29 May, 2005.

Cook, P. S., & Laughlin, J. O. (1999, December). *Toward sustainable forest management: Part I—Certification program*. Moscow: Idaho Forest, Wildlife and Range Policy Analysis Group, University of Idaho.

Dasgupta, K., Susmita, B., Benoit, L., Hua, W., & Wheeler, D. (2005). Confronting the environmental Kuznets curve. In R. Stavins (Ed.), *Economics of the environment* (5th ed., pp. 399–422). New York, NY: W.W. Norton.

Food and Agriculture Organization of the United Nations (FAO). (2001). *Use of criteria and indicators for monitoring, assessment and reporting on progress toward sustainable forest management in the United Nations Forum on Forests* (Report prepared for the International Expert Meeting on Monitoring, Assessment and Reporting on Progress Toward Sustainable Forest Management). Yokohama, Japan: Author.

Food and Agriculture Organization of the United Nations (FAO). (2005). *A national report on the forestry policy of Ghana* (FAO Forestry Paper No. 132/2005). Rome, Italy: Author.

Food and Agriculture Organization of the United Nations (FAO). (2010a). Extent of appropriate technology for timber harvesting. In *Global forest resources assessments—Country report, Ghana*. Rome, Italy: Author.

Food and Agriculture Organization of the United Nations (FAO). (2010b). Extent (ha) of area under natural forest. In *Global forest resources assessments—Country report, Ghana*. Rome, Italy: Author.

Food and Agriculture Organization of the United Nations (FAO). (2014). Trend in deforestation rates. In *Forest resource assessment—Country report, Ghana*. Rome, Italy: Author.

Forestry Commission (FC). (2006). *Area (ha) of forest disturbed by logging, fire, insects and diseases*. Accra, Ghana: Author.

Forestry Commission (FC). (2012). Ghana Forest Investment Programme Plan and REDD Plus Readiness Progress Facts Sheets. Submitted to the FCPF. Accra, September 2012.

Forestry Commission (FC). (2013). *Ghana forest plantation strategy 2014–2050*. Accra, Ghana: Author.

Forestry Commission (FC). (2014). *REDD+ mechanism in Ghana: Strategic environmental and social assessment (SESA)*. Accra, Ghana: Author.

Forestry Commission (FC). (2015). *National REDD+ strategy*. Accra, Ghana: Author.

Ghana Statistical Service (GSS). (2010). *Population projection by sex 2010–2014*. Accra, Ghana: Author.

Gottlieb, R. (2001). *Environmentalism unbound: Exploring new pathways for change*. Cambridge, MA: MIT Press.

Government of Ghana. (2003). *Ghana poverty reduction strategy: An agenda for growth and prosperity: 2003–2005*. Accra, Ghana: Author.

Henwood, K. (2001). *Exploring linkages between the environment and health: Is there a role for environmental and countryside agencies in promoting benefits to health?* Unpublished report, School of Health Policy and Practice, University of East Anglia, Norwich, UK.

Houghton, R. A. (2003). *Revised estimates of the annual net flux of carbon to the atmosphere from changes in land use and land management, 1850–2000. Tellus B, 55*(2), 378–390. doi:10.1034/j.1600-0889.2003.01450.x

Hüllermeier, E., & Fürnkranz, J. (2004). *Comparison of ranking procedures in pairwise preference learning*. Retrieved from https://www-old.cs.uni-paderborn.de/fileadmin/Informatik/eim-i-is/PDFs/IPMU2004.pdf

Intergovernmental Panel on Climate Change. (2006). *IPCC Guidelines for National Greenhouse Gas Inventories*. Vol. 4, Agriculture, Forestry and Other Land-use. Technical support Unit, Kanagawa, Japan: Author.

Institute of Statistical, Social and Economic Research (ISSER). (2008). *The state of the Ghanaian economy report*. Legon, Ghana: Author.

International Tropical Timber Organization (ITTO). (2005). *Is forest management improving in the tropics?* (International Tropical Timber Organization Report on Status of Tropical Forest Management). Yokohama, Japan: Author.

ITTO (2010). *International Tropical Timber Organization Report on Status of Tropical Forest Management: Is forest management improving in the tropic?* Special edition, 2005. Yokohama, Japan: Author.

Kodum-Agyemang, M. A. (2013). *REDD + communication strategy*. Accra, Ghana: Forestry Commission.

Landres, P. B. (1992). Ecological indicators: Panacea or liability?. In D. H. McKenzie, D. E. Hyatt, & J. E. McDonald (Eds.), *Ecological indicators* (Vol. 2, pp. 1295–1319). London, UK: Elsevier Applied Science.

Macgregor, C. (2000, June). *Applying an analytical model for assessing community sustainability: Some preliminary results from northern Australian remote towns*. Paper presented at the First National Conference on the Future of Australia's Country Towns, Bendigo, Victoria, Australia.

Mandal, G., & Joshi, S. P. (2015). Biomass accumulation and carbon sequestration potential of dry deciduous forests. *International Journal of Energy & Development*, *30*(1), 51–63.

McCool, S., & Stankey, G. (2001). Representing the future: A framework for evaluating the utility of indicators in the search for sustainable forest management. In R. J. Raison, A. G. Brown, & D. W. Flinn (Eds.), *Criteria and indicators for sustainable forest management* (pp. 93–105). Wallingford, UK: CABI Publishing.

Mendoza, G. A., & Prabhu, R. (1998). *Multiple criteria analysis for assessing criteria and indicators in sustainable forest management: A case study on participatory decision-makin —Part II*. Bogor, Indonesia: CIFOR.

Mendoza, G. A., & Vanclay, J. K. (2008). *Trends in forestry modelling*. Retrieved from http://epubs.scu.edu.au/cgi/viewcontent.cgi?article=1479&context=esm_pubs

Ministry of Environment and Science (ME & S). (2005). *Republic of Ghana biodiversity status report* (Third National Report). Accra, Ghana: Author.

Ministry of Finance and Economic Planning (MF & EP). (2008). *Ministry of Finance and Economic Planning of the Republic of Ghana budget document for the year 2008*. Delivered to Parliament on behave of the President by Mr. Baah Wiredu (Sector Minister), Accra, Ghana.

Ministry for Lands and Forestry (ML & F). (2005, October). An interview with the Sector Minister (Hon. D. Fobi) at Meet the Press, Accra, Ghana.

Ministry for Lands and Forestry (ML & F). (2010). *Extent of financial commitment* ($) *to sustainable forest management*. Accra, Ghana: Author.

Ministry of Lands and Natural Resources (ML & NR). (2014a). *Forest Investment Programme (FIP) —Enhancing carbon stocks in natural forests and agroforest landscapes: Process framework*. Accra, Ghana: Author.

Ministry of Lands and Natural Resources (ML & NR). (2014b). *Forest Investment Progamme (FIP)—Enhancing carbon stocks in natural forests and agroforest landscapes: Pest management plan*. Accra, Ghana: Author.

Moctar, T. (2005). *Land and water resources of the world: Global Environmental Facility Team*. Washington, DC: World Bank.

Morgan, M. (2006). States Country Background Notes. Annual cost of environmental degradation in developing countries. *New Directions for Evaluation*, *122*, 31–39.

Nketiah, K. S., Wieman, A., & Asubonteng, K. O. (2004). *Natural resource management in Ghana: Challenges to professionalism*. Wageningen, The Netherlands: Tropenbos International.

Nunoo, E. K. (2007). EIA performance standards and thresholds for sustainable forest management. In M. Schmidt, J. Glasson, L. Emmelin, & H. Helbron, (Eds.), *Standards and thresholds for impact assessment* (pp. 229–240). Berlin, Germany: Springer Verlag.

Nunoo, E. K. (2010). *Measuring progress towards sustainable forest management and policy Implications: A case study in the high forest zone of Ghana*. Saarbrucken, Germany: Lambert Academic Publishing.

Ober, A. (1998, March). *Criteria and indicators of sustainable forest management and related certification schemes. Interorganizational processes of implementation in global forestry*. Paper

presented at the 39th Annual Convention of the International Studies Association (ISA), Minneapolis, Minnesota, USA.
Oliver, C. D. (2003). Sustainable forestry: What is it? How do we achieve it? *Journal of Forestry*, *101* (5), 8–14.
Peterson del Mar, D. (2006). *Environmentalism: A short history of a big idea*. Harlow, UK: Pearson/ Longman.
Prescott-Allen, R. (1999). *The wellbeing of nations*. Cambridge, UK: IUCN.
Radulescu, C. V. (2009). Towards an ecologically sustainable economy? *Metalurgia International*, *14* (Suppl. 5), 146–149.
Raison, R. J., Brown, A. G., & Flin, D. (Eds.). (2001). *Criteria and indicators for sustainable forest management*. Wallingford, UK: CABI Publishing.
Sackey, A. (2007). Assessment of forest management practices in Ghana—A case study of some forest districts in Ghana. *The IMRE Journal*, *1*(2), 1–18.
Sheil, D., Nasi, R., & Johnson, B. (2004). Ecological criteria and indicators for tropical forest landscapes: Challenges in the search for progress. *Ecology and Society*, *9*(1), 7.
Tropenbos. (2010). REDD+ in Ghana: A simplified explanatory leaflet for forest dependent people and traditional authorities. Prepared by TBI Ghana for the Forestry Commission UN-REDD Programme. 2011. UN-REDD Programme Newsletter, 25.
United Nations Conference on Environment and Development (UNCED). (1992). Combating desertification. U.N Doc. 1992. *A/Conf*, *2*(1), 151/26.
Wolfslehner, B., & Harald, V. (2008, July). Evaluating sustainable forest management strategies with the Analytic Network Process in a Pressure-State-Response framework. *Journal of Environmental Management*, *88*(1), 1–10. doi:10.1016/j.jenvman.2007.01.027
World Bank. (1994). *The Human Face of the Urban Environment*: *Proceedings of the Second Annual World Bank Conference on Environmentally Sustainable Development*. Retrieved from http://documents.worldbank.org/curated/en/1995/09/697059/human-face-urban-environment-proceedings-second-annual-world-bank-conference-environmentally-sustainable-development
World Bank. (2004, November). *Environment of Ghana at a glance 2004*. Washington, DC: Author.
World Bank. (2006). *Ghana: Natural Resource Management and Growth Sustainability. Economic and Sector Work in Ghana*. Washington DC: World Bank.
World Bank. (2008). *Environmental sustainability: An evaluation of World Bank group support*. Washington, DC: Author.
World Conservation Union (IUCN). (1999). *Assessing progress towards sustainability*. (International Conservation Union. 1999 Workshop Report and Training Notes).