

# Supplementary Materials: Theory-of-Change Development for Evaluation of Forest Stewardship Council Certification of Sustained Timber Yields from Natural Forests in Indonesia

Claudia Romero and Francis E. Putz

**Table S1.** Ranking of FSC's indicators as they directly pertain to the achievement of STY goals of the Indonesian FSC certification standard. Ranking: Most critical (green: 17 indicators); critical (white: 22 indicators); and tangential (purple; 6 indicators; Total N = 45). FME: Forest Management Enterprise.

Principle	#	STY Directly Related Indicators
1. Forest management shall respect all national and local laws and administrative requirements.	1.5.1	The Forest Management Unit(s) (FMU) shall be protected by the FME from unauthorized harvesting activities, and other activities not controlled by the forest manager or local people with use rights. (e.g., settlement, illegal harvesting, poaching).
	1.5.3	The FME shall document and map any changes in land use due to unauthorized activities, including but not limited to any area illegally harvested or cleared for agriculture or settlement.
	1.5.4	The FME shall take measures when illegal activities are detected.
	1.6.1	The FME shall have a publicly available policy endorsed by the owner or most senior management explicitly stating a long-term commitment to forest management practices consistent with the FSC Principles and Criteria for Forest Stewardship.
5. Forest management should strive toward economic viability, while taking into account the full environmental, social, and operational costs of production, and ensuring the investments necessary to maintain the ecological productivity of the forest.	5.1.3	The revenue estimates shall be based on all available information, and consistent with the expected rate of harvest of forest products and/or provision of other products or services.
	5.1.4	If the budget shows a deficit for the year, the FME shall demonstrate how the shortfall will be covered whilst ensuring that the management planning is implemented in the long term.
	5.2.2 L	FME shall promote the development of markets for and sustainable harvesting of common, lesser-known forest species, including NTFPs.
	5.3.1	Harvesting techniques shall be designed to avoid log breakage, timber degrade and damage to the forest stand and other resources.
	5.3.2	Waste generated through harvesting operations, on-site processing and extraction shall be minimized, e.g., by using it to protect soils or skid trails.
	5.3.3	Harvested and processed wood and/or other products processed on-site shall be transported from the forest before any deterioration occurs.
	5.3.4 L	Strategic and tactical/operational harvest planning and harvest operations shall be carried out in accordance with national best practice guidelines (where these do not exist or are inadequate, for tropical high forest the FAO Model Code of Forest Harvesting Practice will apply).
	5.6.1	The FME shall have a clear methodology to determine the allowable cut.
	5.6.2	The methodology for allowable harvest level shall be based on conservative, well-documented and most current estimates of growth and yield in order to not jeopardize the forest's productive potential and/or the potential to maintain its environmental or social services in the medium to long term.
	5.6.3	The FME shall keep clear, accurate and up-to-date records of harvested volumes of all commercial timber species, and of the commercial harvest of any non-timber forest products. Actual harvests do not exceed calculated replenishment rates over the long term.

	5.6.5	Based on growth and yield data the FME shall ensure that annual production is in accordance with the capability of forest productivity.
6. Assessment of environmental impacts shall be completed—appropriate to the scale, intensity of forest management and the uniqueness of the affected resources—and adequately integrated into management systems. Assessments shall include landscape level considerations as well as the impacts of on-site processing facilities. Environmental impacts shall be assessed prior to commencement of site-disturbing operations.	6.3.1	The FME shall have site-specific data or published analyses of local forest ecosystems that provide information on the FMU with regards to: -Regeneration and succession; Genetic, species and ecosystem diversity; and, natural cycles that affect productivity.
	6.3.2	Forest regeneration and succession. In natural and other non-plantation forest areas managed for production, the silvicultural and/or other management systems of the FMU shall be designed to encourage and take advantage of natural regeneration (e.g., identification, retention and mapping of seed trees, timing of harvesting, design and size of harvesting areas, short and long term post-harvest treatment of the site), unless data show that enrichment planting will enhance or restore genetic, species or ecosystem diversity.
	6.5.10	Harvesting and extraction methods are designed to minimize damage to residual trees and regeneration.
	6.5.6	Training shall be given to FME staff and contractors to meet guidance requirements.
	7.1.10	Before the commencement of harvesting and road construction, there shall be clear and accessible maps (at a scale appropriate to guide planning and supervision) describing the forest resource base including protected areas, planned management activities and land ownership, at appropriate scales for their respective purposes.
7. A management plan—appropriate to the scale and intensity of the operations -shall be written, implemented, and kept up to date. The long term objectives of management, and the means of achieving them, shall be clearly stated.	7.1.11	The management planning and/or supporting documents of the FME shall include a description and justification of harvesting techniques and equipment to be used (see also Criterion 6.5).
	7.1.12L	Procedures for monitoring forest regeneration and growth shall be documented.
	7.1.13	The need for fire management and control shall be evaluated and is documented.
	7.1.14	There shall be maps showing planned management in the short term and longer term.
	7.1.6	The management planning and/or supporting documents of the FME shall include a description of the silvicultural and/or other management system, based on the ecology of the forest in question and information gathered through resource inventories (see also Criteria 5.6, 6.3, 8.1, 8.2).
	7.1.7	The management planning and/or supporting documents of the FME shall include a clear rationale for rate of annual harvest and species selection (see also Criterion 5.6).
	7.1.8	The management planning and/or supporting documents of the FME shall specify environmental safeguards based on environmental assessments (see also Criterion 6.1, 9.3).
	7.2.1	The management planning and supporting documentation of FME shall be revised and updated on a timely and consistent basis.
	7.2.2	The management planning and supporting documentation of FME shall incorporate the results of monitoring and/or new scientific and technical information.
	7.2.3	The management planning and supporting documents of FME shall incorporate the results of changing environmental, social and economic considerations.
	7.2.4	FMEs shall assign specific staff for timely updating of the management plan.
	7.2.5	The management planning reviewed at least every five (5) years shall be updated with the results of monitoring.
	7.3.2	All workers (including contractors and their workers) shall be trained to implement the tasks and responsibilities effectively and safely.
	7.3.3	All forest workers shall demonstrate a working knowledge and compliance with relevant codes of practice, operational guidelines

8. Monitoring shall be conducted—appropriate to the scale and intensity of forest management—to assess the condition of the forest, yields of forest products, chain of custody, management activities and their social and environmental impacts.		and other accepted norms or agreements relevant to their responsibilities Relevant laws are listed in Annex A.
	7.3.4	All workers (including contractors and their workers) shall be supervised to ensure that they implement their tasks effectively and safely, and the FME itself monitors the quality of their work.
	7.3.5	Appropriate to the scale and intensity of the operation there shall be a policy for training, qualifications, and recruitment that includes skill and experience as the basis for recruitment, placement, training and advancement of staff at all levels.
	8.1.2	The frequency and intensity of the monitoring shall be defined and is appropriate to the scale and intensity of the forest operations as well as the relative complexity and fragility of the resources under management.
	8.1.3	The described procedures shall be consistent and replicable over time to allow comparison and assessment of change.
	8.1.4	Monitoring records shall be available, complete and up to date.
	8.2.1	Yields of all forest products shall be collected and recorded. Growth rates, regeneration and condition of the forest.
	8.2.2	A periodic general inventory of forest stock and condition (including presence of pests, diseases, evidence of soil compaction, erosion, invasive unwanted species etc.) shall be carried out, which covers the whole area of production forest on a rolling basis and which supplements the information provided by pre- and post-harvest inventory.
	8.2.3	The data collected during pre- and post-harvest inventory and general inventory shall be sufficient to identify and describe significant changes in the forest flora over time.
	8.3.2 L	Volume and source data on harvested forest products shall be available (i.e., scaled, inventoried, measured) in the forest, in transport, at intermediate storage yards (e.g., log yards), and processing centres controlled by FME.
	8.4.1	The FME shall be able to demonstrate that the monitoring results as specified under Criteria 8.1 and 8.2 are incorporated into the revision of the management planning.
	8.4.3	The Monitoring reports indicate how management prescriptions should be changed based on new ecological, silvicultural or market information.

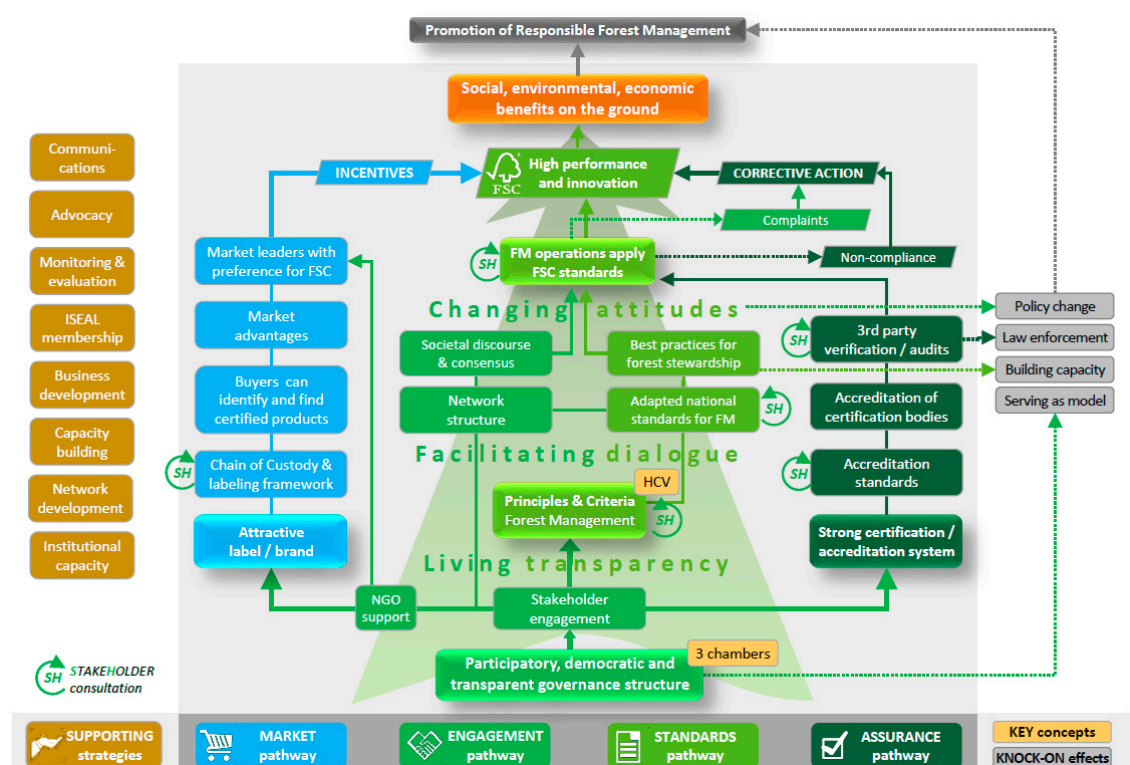
**Table S2.** Description of indicators indirectly related to STY from the Indonesian FSC certification standard ( $N = 21$ ).

Principle	#	STY Indirectly Related Indicators
1. Forest management shall respect all national and local laws and administrative requirements.	1.1.2	If any non-compliances with legal or regulatory requirements have been identified by the FME or by third parties, they shall have been documented, were promptly corrected, and effective action has been taken to prevent their recurrence.
	1.1.3 L	The FME shall have copies of existing relevant national laws, legislative and regulatory requirements available in the forest management unit.
	1.1.4	In case any conflicts with legal or regulatory requirements have been identified by the FME or by stakeholders, they shall be documented and actions implemented with the designated authority to resolve and prevent their recurrence.
	1.2.3	The FME shall ensure that the requirements of this Criterion are also met by contractors.
5. Forest management should strive toward economic viability, while taking into account the full environmental, social, and operational costs of production, and ensuring the investments necessary to maintain the ecological productivity of the forest.	5.1.1	There shall be a budget showing the expected costs and revenues for the FME for at least the current financial year as well as operational costs necessary to maintain certifiable status (e.g., management planning, road maintenance, silvicultural treatments, long-term forest health, growth and yield monitoring, and conservation investments).
	5.1.2	5.1.2: The budget shall include costs for all significant activities and necessary investments (including the cost of meeting all social and environmental commitments) identified or implied in the forest management plan and associated policies and planning documentation.
6. Assessment of environmental impacts shall be completed—appropriate to the scale, intensity of forest management and the uniqueness of the affected resources—and adequately integrated into management systems. Assessments shall include landscape level considerations as well as the impacts of on-site processing facilities. Environmental impacts shall be assessed prior to commencement of site-disturbing operations.	6.1.7 S	The FME shall be able to demonstrate knowledge of possible negative impacts of forest management activities and seek to mitigate or reduce them.
	6.1.8 S	Before initiating any operation, the possible negative environmental impacts shall be identified and the operation is designed to minimize them. Assessments do not need to be documented unless legally required.
	6.3.3	Where degraded sites are identified in the FMU, the silvicultural and/or management systems shall include a program for the restoration of these sites.
	6.3.4	Old, non-commercial trees; trees with special ecological value; standing dead trees; and dead fallen wood shall all be systematically retained within the production area of the FMU, and in sufficient quantity to support wildlife species dependent on old trees and dead wood across the FMU.
	6.3.5	Site preparation and harvesting methods shall have been designed to minimize soil compaction and maximize the retention of nutrients on site.
	6.3.6	Protective areas shall be established between the management areas and the areas that have high risk of fire or erosion (e.g., bordering on pastures or small farming areas).
	6.3.7	There shall be no evidence that the harvesting of material from the site is reducing the potential productivity of the soil in the long term.
	6.5.1	Forest operations with adverse environmental impact (as identified in 6.1) shall have written guidelines defining acceptable practices which are available to forest managers and supervisors. Such operational guidelines shall meet or exceed national or regional best management practices.

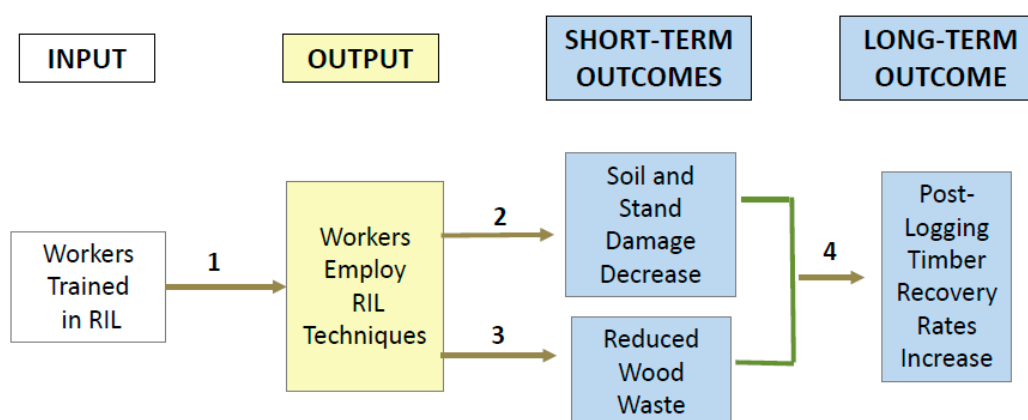
7. A management plan—appropriate to the scale and intensity of the operations—shall be written, implemented, and kept up to date. The long term objectives of management, and the means of achieving them, shall be clearly stated.	6.5.2	Guidelines developed in terms of indicator 6.5.1 shall be implemented during operations and planning.
	6.5.5	Topographic maps shall be prepared before logging or road construction occurs.
	7.1.1	The management planning and/or supporting documents of the FME shall include management objectives for the FMU under evaluation (see also Criterion 1.6).
	7.1.2	The management planning and/or supporting documents of the FME shall include in the objectives conservation and/or restoration of representative samples of natural forest within the FMU (see also Criteria 1.6, 5.5 and 6.2).
	7.1.3	The management plan and / or supporting documents of the FME shall include: –7.1.3.1 a description of the forest resources to be managed, –7.1.3.2 environmental limitations, –7.1.3.3 land use and ownership status, –7.1.3.4 socio-economic conditions, and –7.1.3.5 A profile of adjacent lands (see also Criterion 5.5).
	7.1.4	The FME shall know and mark on maps areas that have been harvested in the past.
	7.3.1	All managing staff and supervisors (including those employed by contractors) shall have adequate education, experience or training to ensure that they are able to plan, organize and supervise forestry operations in accordance with the Enterprise’s plans, policies and procedures.

**Table S3.** Assumptions (numbered arrows) and possible indicators on the detailed theory-of-change (ToC) related to worker training in reduced-impact logging (RIL) depicted in Figure S2.

Level In ToC	Arrow #	Assumption	Indicator
<b>Output</b>	1	Workers Employ RIL Techniques	# Workers understand what constitutes RIL. # Workers that are sufficiently skillful at RIL. # Workers motivated to apply RIL.
<b>Short-term Outcomes</b>	2	Stand and Soil Damage Decrease	Topographic and stock maps are sufficiently accurate. Skid trails are planned and opened to minimize impacts and maximize efficiency. Tractor drivers keep to planned skid trails unless they receive permission to deviate. Tractor drivers rarely blade surface soil. Tractor driver assistants pull out winch cables. Fellers successfully follow directional felling instructions. Road corridor widths (need to be restrained).
	3	Reduced Wood Waste	Stumps height (cm; i.e., need to be low). Damage to boles of felled trees and neighbors (i.e., reduced through use of directional felling). Logs are bucked to maximize timber yields. # Hollow trees felled (i.e., suspect standing trees subjected to “plunge test” and not felled if heart-rotted or hollow). # Merchantable logs abandoned in the forest or on log landings
<b>Long-term Outcome</b>	4	Post-logging Timber Recovery Rates Increase	Soil compaction and erosion (that slow trees recruitment and growth). Commercial species recruitment (# Individuals / sp). Area (km <sup>2</sup> infested by lianas), # Non-commercial pioneer trees, and other silvicultural weeds. Volume (m <sup>3</sup> ) Standing timber stocks of commercial species. Post-logging tree mortality rates.



**Figure S1.** Graphic depiction of FSC's ToC with information on reinforcing pathways and supporting strategies all toward the goal of promoting responsible forest management.



**Figure S2.** Details of the portion of the theory-of-change presented in Figure 1 that relates to the hoped-for benefit of worker training in reduced-impact logging (RIL). Numbers represent assumptions (See Table S3).