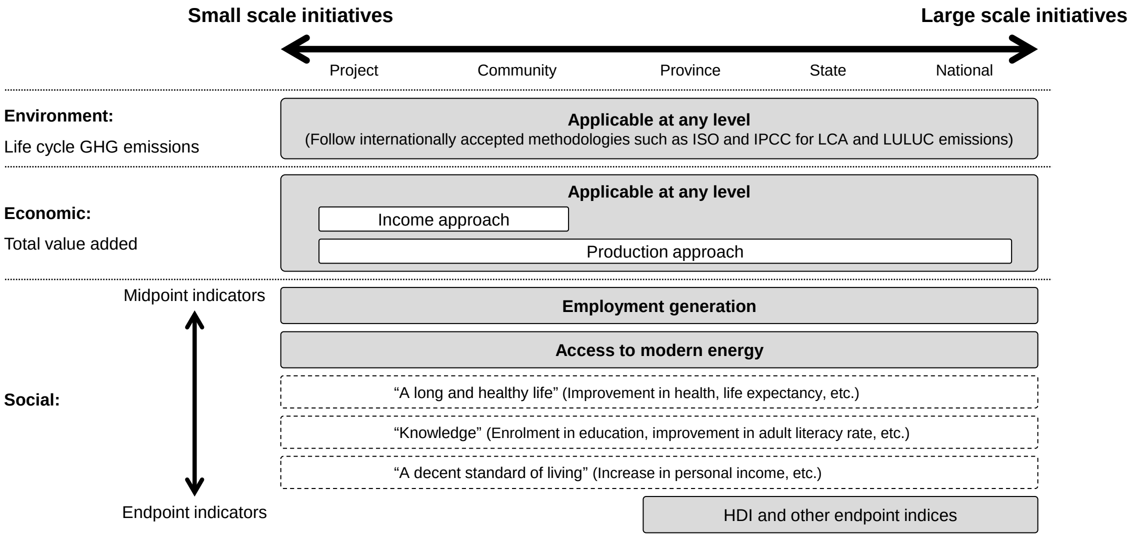
Appendix I. Sustainability Indicators of ERIA WG Methodology

The sustainability indicators currently employed in the ERIA WG methodology are summarized in Figure A1-1. These indicators were carefully selected from existing indicators so that they could be applied to a variety of biomass utilization projects, ranging from small to large scale, in both ex-ante and ex-post assessments. Each indicator is summarized in the following sections.

Figure A1-1. Indicators of Sustainability of the ERIA WG methodology



1. Environmental Sustainability Indicator

Although the WG recognizes the importance of other environmental impact categories, such as such as impacts on air, water and soil quality, and biodiversity, the concept of Life Cycle GHG (LC-GHG) emissions, or their savings, is employed as the WG environmental sustainability indicator in the ERIA WG methodology. This is because climate change caused by GHG emissions is one of the most important concerns, affecting all countries in East Asia.

In order to quantify the emissions of GHGs, including carbon dioxide and other gases, it is necessary to take each step of the Life Cycle Assessment (LCA) standardized in ISO 14040s.

The material and energy inputs and outputs necessary for estimating GHG emissions, the so called Life Cycle Inventory (LCI) data, are gathered based on the goal and scope defined at the beginning of a study. Then the quantities of GHGs are computed with use of GHG emission factors that are, for example, prepared nationally, provided by IPCC (default values) or experimentally-measured. The amounts of the respective GHG emissions are aggregated into the quantity of carbon dioxide equivalent weight of greenhouse gases (kg- or tons-) with use of GWP (Global Warming Potentials) (IPCC, 2007). This calculation can be expressed by Equation (A1-1).

$$LCGHG = \sum_{i,j} \left(GHG_{i,j} \times GWP_i \right) \qquad \text{(A1-1)}$$

where *i* is the greenhouse gas (e.g. carbon dioxide, methane and/or nitrous oxide) *j* is the life cycle stage of biomass utilization for energy (e.g. feedstock cultivation, feedstock collection and conversion process of biomass into energy), *LCGHG* is life cycle GHG emissions [/FU], $_{,j}$ is the amount of the GHG *i* in the stage j [/FU], is the global warming potential for the GHG *i* and FU is the functional unit (e.g. per hectare per year, per 1 kiloliter or GJ of bioenergy carrier, etc.).

In case a biomass-derived product is comparable and replaceable with fossil-based product, e.g. the case that bioethanol replaces gasoline, GHG savings is a more convenient indicator to understand how much GHG emissions could be reduced by the replacement. This is computed with Equation (A1-2).

$$S = LCGHG_{Fossil} - LCGHG_{Biomass} \qquad \text{(A1-2)}$$

where S is GHG savings, is life cycle GHG emissions from a fossil-based product and is life cycle GHG emissions of a biomass-derived product.

2. Economic Sustainability Indicators

There are two levels of indicator: a master indicator and multiple sub-indicators. The sub-indicators are: employment, net profits and tax revenues while master indicators are TVA (Total Value Added) and the foreign exchange savings. All these indicators can be applied to any scale, from project to national level, except for foreign exchange savings which is only relevant at the national level.

2.1. Master Indicator – Total Value Added

TVA was originally used in national accounts as a measure in economics of the value of goods and services produced in an area, industry or sector of an economy. TVA as used in this study is the sum of the value added generated out of the development of biomass, including, production, further conversion or processing, and by-products. In the economic assessment, the TVA is rescaled by production quantity and thus becomes TVA per unit of biomass production.

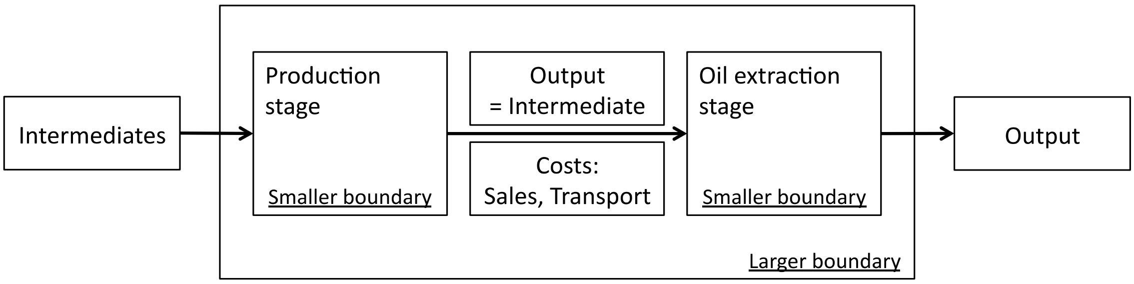
As in national accounts, TVA in this study is also calculated as output value minus costs of intermediates:

$$\begin{aligned} \text{TVA} &= \text{Output value (or Gross revenue)} - \text{Cost of intermediates} \\ &= \sum \text{Price} \times \text{Output quantity} - \text{Cost of intermediates} \qquad \text{(A1-3)} \end{aligned}$$

where gross revenue is simply the product of price and quantity (applies to both main product and by-products), and intermediates include goods and services, other than fixed assets, used as inputs into the production process of biomass, which are produced elsewhere in the economy or are imported. It should be noted that land, labor, and capital are primary inputs and are not included among intermediates. This is equivalent to the production approach of measuring GDP while the method proposed in the previous report was an income approach, which may be complicated for use by professionals not having a background in economics.

This TVA measure can be applied to any stage of biomass production and can include any step of biomass production. The user only needs to know the value of intermediate input and the output value generated out of the boundary. Anything inside the boundary is a “black box” and does not need to be calculated. The boundary can be defined by the user. For example, as shown in Figure A1-2, the boundary can contain only production of biomass, or both production of biomass and oil extraction. In the later and larger boundary, the “output” value of biomass becomes an “input” in the oil extraction stage and thus when calculating the two stages together, one only needs the final output value of biomass oil, while not caring about the output value of biomass.

Figure A1-2. Input-Output Boundaries for TVA Calculation



The boundary in Figure A1-2 can be equally extended to include more stages, such as esterification, which are often undertaken in the case of producing biodiesel.

The master indicator can be supplemented by a few sub or component indicators, such as labor income, net profit, tax revenues and foreign exchange savings.

2.2. Sub-Indicators for Economic Pillar

2.2.1. Labor Income (Wage)

Labor income or wage is another indicator for assessing the economic impact of the biomass industry and is put as a sub-level indicator to supplement the master indicator. Labor income, or wage, or personnel remuneration refers to the total salaries and wages paid to the employees in the different firms or activities involved in the biomass utilization in exchange for their labor. This includes the labor income from both the production stage and the plantation and processing stages of raw material to bioenergy. This is computed as Equation (A1-4):

$$\text{Labor Income} = \text{Total person-days} \times \text{Average wage per person-day} \quad \text{(A1-4)}$$

In most cases, the labor requirement is expressed in terms of person-days. As such, the necessary conversion may be done to express person-days as number of persons hired. The resulting figure is a more concrete representation or estimation of the employment impact.

2.2.2. Net Profit

Net profit is a key indicator that is closely monitored by investors. It is also an indicator used to demonstrate the sustainability of a biomass business. If a negative profit is consistent, investors will finally pull out of the biomass business and the industry cannot be sustained.

Profit can be influenced by the government, and thus it is also of interest to the government. If government finds that the profit is not attractive to private investors, it can reduce taxes or provide subsidy to the biomass industry.

2.2.3. Tax Revenues

Tax revenue is the income generated for the government from the entities involved in each production process. Each country may have a different tax portfolio, and thus the calculation will be diverse. A typical example is computed as Equation (A1-5):

$$\text{Tax} = \text{Total taxable income} \times \text{Tax rate} \qquad \text{(A1-5)}$$

Where

Total taxable income

= Income from main product (Profit per unit of product A × Volume of A)

+ Income from by-product (Profit per unit of by-product B × Volume of B) (A1-6)

Taxes generated from the biomass industry can be obtained by multiplying the prevailing tax rate by the total taxable income of each sector (i.e. copra, unrefined oil, and coconut methyl ester producers in the case of biodiesel production from coconut), as can be described as Equation (A1-7).

$$\text{Tax} = \text{Total taxable income from all processed products} \times \text{Tax rate} \qquad \text{(A1-7)}$$

3. Social Sustainability Indicator (Human Development Index)

Among the social sustainability indicators of the ERIA WG methodology, the basic concepts of employment and access to modern energy are already addressed in Chapter 3.4. This section deals with the Human Development Index (HDI).

Social issues in the growing markets for biomass energy utilization are expected to become prominent as the producers and consumers of bioenergy may live in different countries. Major positive social impacts of bioenergy include enhancing energy security, creating job opportunities, etc. On the other hand, negative social impacts expected in biomass energy utilization are food insecurity, land use conflicts with indigenous inhabitants, exploitative working conditions, etc. To capture the holistic picture of development across countries, the United Nations Development Programme (UNDP, 2011) has used the Human Development Index (HDI). This essentially takes into account the measures for living a long healthy life (by life expectancy), being educated (by adult education and enrolment at primary, secondary and tertiary levels) and having a decent standard of living (by purchasing power parity, PPP). The WG adopted the HDI as the indicator to evaluate the social sustainability of biomass energy utilization. Although the pilot studies conducted by the WG (ERIA, 2010) found difficulty in applying HDI to biomass projects at the small scale or community level, HDI could be applied to projects at large scale or national level. The calculation of HDI can be described as Equation (A1-8) and Table A1-1.

$$\text{HDI} = 1/3 \times (\text{Life expectancy index} + \text{Education index} + \text{GDP index}) \qquad \text{(A1-8)}$$

Table A1-1: Calculation of HDI

Index	Measure	Minimum value	Maximum value
Life expectancy	Life expectancy at birth (LE) LE index = (LE-)/(-)	25 years	85 years
Education	Education index = ALI×2/3+GEI×1/3 Adult literacy index (ALI) = (ALR-)/(-) where ALR: Adult literacy rate [%] Gross enrolment index (GEI) = (GER-)/(-) where GER: Gross enrolment ratio [%]	0%	100%
GDP	GDP index = {ln(GDP)-ln( )}/{ln( )-ln( )} where GDP: GDP (PPP) per capita [USD]	100 USD	40,000 USD

Appendix II. Soil Sustainability

Soil quality and sustainability evaluation is a fundamental concept bridging between the utilization and protection aspects of soil-use planning. Sustainability analysis of soil-use can performed for any individual soil function or groups of soil functions in defined land use systems in a comparative manner, taking the potential effects of degradation into account (Tóth, *et al*., 2007).

Decline of soil fertility, carbon, and biodiversity, lower water retention capacity, disruption of gas and nutrient cycles and reduced degradation of contaminants are among the results of the soil degradation processes. Soil degradation has a direct impact on the environmental quality that prevents the soil from performing its services to society and ecosystems at required levels, such as:

- Biomass production
- Storing, filtering and transforming nutrients, substances, and water
- Biodiversity pool such as habitats, species, and genes
- Source of raw materials
- Acting as carbon pool

The maintenance of the fertility of the soil is the first condition of any permanent system of agriculture. To ensure the sustainability of biomass energy utilization, International Sustainability & Carbon Certification (ISCC) announced that biomass should be produced in an environmentally responsible way (ISCC, 2011). This includes the protection of soil, water and air, and the application of Good Agricultural Practices (GAP). To address the impacts of biomass energy utilization on soil sustainability, the following GAP principles should be considered.

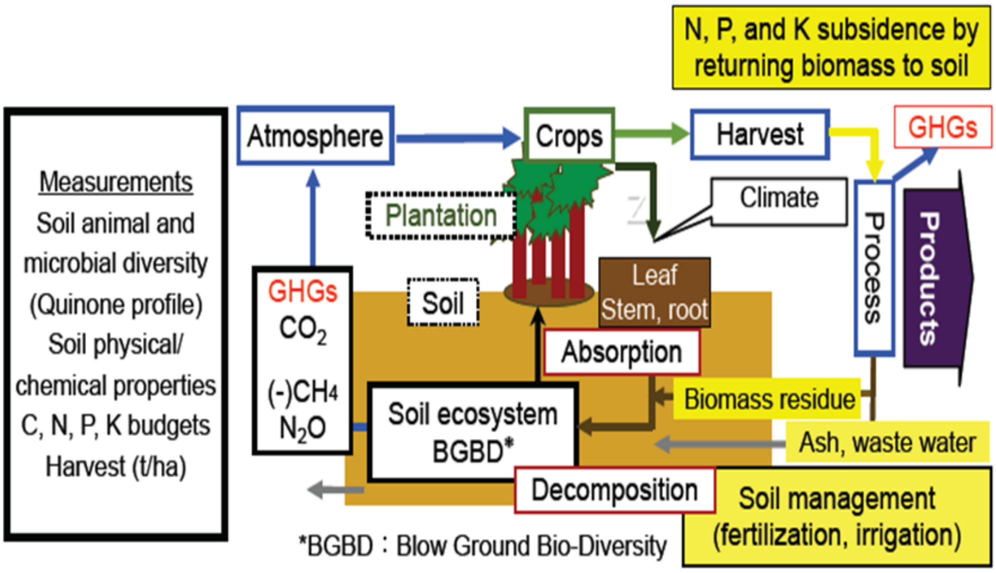
- Field cultivation techniques are used to reduce the possibility of soil erosion
- Soil organic matter is maintained/preserved
- Organic matter, if used, is evenly spread throughout the production area
- There is a restriction on burning of organic matter as a part of the cultivation process
- Techniques have been used that improve/maintain soil structure, and avoid soil compaction.

The sustainable use of soil resources depends on three factors: soil characteristics, related environmental (climate, hydrologic etc.) conditions and land use. These factors interact in a systems-based fashion, where the change in one factor causes alteration in the others. Therefore the sustainable use of soil resources is a dynamic category. It is important to assess our soil resources from this standpoint and to consider soil as the prime object of sustainable use in relation to land management under given (changing) natural conditions. The sustainability of soil-use can be achieved by practical methods of management and can only be guaranteed if the material and energy flow associated with soil processes are controlled and positively influenced. This means the management and maintenance of certain level of soil characteristics, which eventually embrace soil quality as well (Tóth, *et al*., 2007).

The GBEP (Global Bioenergy Partnership) sustainability indicator for bioenergy considered soil quality as an indicator in its environmental pillar. The description of this indicator is "Percentage of land for which soil quality, in particular in terms of soil organic carbon, is maintained or improved out of total land on which bioenergy feedstock is cultivated or harvested". In this sustainability indicator, the term "soil quality" is described particularly only as soil organic carbon. Actually, to describe the soil quality comprehensively, the chemical, physical, and biological properties of soil should be measured. In terms of chemical soil quality, the C, N, P, and K contents are usually used as general indicators. Soil animal and microbial diversity can be used as parameters of biological soil quality. Soil erosion and compaction or soil structures are often used to measure physical soil quality. Figure A2-1 describes the relationship between cultivation and productivity and the measurement parameters for evaluate soil quality.

Society needs simple measurements to compare the options for utilizing soil functions and measuring the risk of that particular utilization leading to soil degradation processes. Soil quality assessment can serve as a basis of this comparison and should be one of the main criteria for planning and practicing sustainable soil-use (Tóth, *et al*., 2007).

Figure A2-1: Relationship between Cultivation and Productivity and the Measurement Parameters for Evaluating Soil Quality.

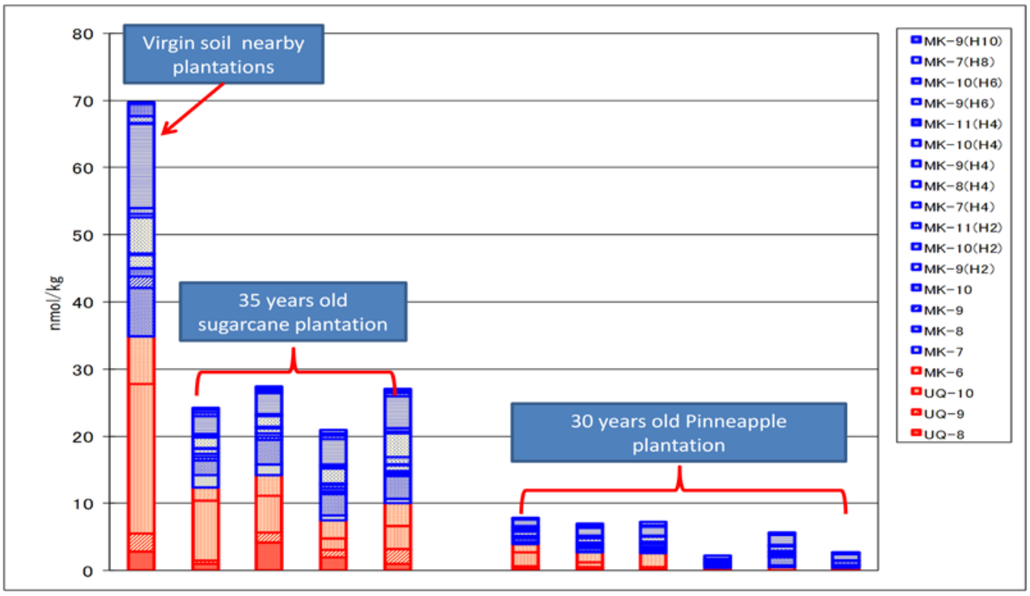


To measure all indicators of soil quality is not easy. Soil organic carbon and the soil's microbial community have a close relationship to soil quality. In living soil around 100 elements and billions of microorganisms work together in synergy. Microorganisms are precisely what differentiate a living soil from a dead soil. Microorganisms decompose and ferment organic matter into humus, containing nutrients and hormones that facilitate plant growth. Typically, microorganisms are responsible for providing hormones, nutrients, and minerals in a useable form to the plants via the root ecology. Microorganisms cohere with soil particles and soil structure, retaining nitrogen and other fertilizing compounds.

Microorganisms have been known to contribute to environmental conservation via organic matter which is predominantly degraded through microbial processes in ecosystems (Baker and Herson, 1994; Fujie, *et al*., 1998; Katayama, *et al*., 1998). The capacity of an ecosystem to degrade organic matter and its response to the changes in environmental conditions not only depend on the total population of microorganisms present in that system but also depend on microbial community structure of that system (Hu, *et al*., 1999; Hasanudin, *et al*., 2004).

The microbial community structure in natural mixed cultures such as soil can be used as an indicator of soil conditions such as: fertility, biodiversity, and the structural condition of soil. Soil organic carbon has a close correlation with microbial community structure, but soil which has a high concentration of organic carbon does not always have high number and species of microbes. Microbial communities in the soil need not only organic carbon for growth and multiplication, but also other organic matter such as nitrogen (N) and phosphorus (P). Therefore, microbial community structure can be promoted as a more representative indicator of soil quality than soil organic carbon. The quinone profile or other microbial identification systems can be used to describe microbial community structure in soil and can therefore be used as an indicator of soil quality. Figure A2-2 shows the effect of sugar cane and pineapple plantation in Lampung Province, Indonesia on the number and diversity of microorganisms, using quinone as an indicator. The concentration of quinone (mmol/kg of soil) can be used as an indicator of the number of microorganisms and species of quinone (Ubiquinone (UQ) and Menaquinone (MK)) can be used as indicators of the diversity of microorganisms in the soil. This result shows that after several years of soil utilization for cultivation, the number and diversity of microorganisms decreased significantly. This information is very useful for describing soil conditions (soil fertility and structure) and the productivity of soil for producing biomass. Based on this information, microbial community structure using quinone profiles can describe soil quality. Soil quality is very important in ensuring the sustainability of biomass production, and quinone profiles can be used as an evaluation index of bioenergy sustainability.

Figure A2-2: Effect of Land Utilisation for Plantations on Microbial Community Structure in the Soil Using Quinone Profile Indicator.



The sustainability of soil-use and preservation of soil resources depends on (i) the ability of soil to perform and maintain its function and (ii) the capacity of soil to respond to impacts over time under the changing pressure of soil degradation threats. Therefore matching soil quality and degradation characteristics over a time period helps in evaluating soil sustainability. Soil sustainability analysis is performed on the basis of numerical indices of a Soil Quality Index (SQI) and a Cumulative Degradation Effect (CDE). A Soil Sustainability Index (SSI), can therefore be defined as Equation (A2-1)

$$SSI = SQI \times (100 - CDE) \qquad \text{(A2-1)}$$

Where:

- *SQI* is the Soil Quality Index, which can be used as an indicator of the "goodness" of soil with regards to functions and responses.
- *CDE* is the Cumulative Degradation Effect (the gradient of the degradation processes), which is scaled inversely, on a proposed 100 point scale. Inverse

scaling in this equation helps to identify the effect of degradation on the function, and provide a realistic SSI (Tóth et.al., 2007).

Based on this equation, soil sustainability is determined by SQI and CDE, which can be explained by concentration and diversity of quinone in the virgin and the present soil condition (calculated from and).

References:

Baker, K. H. and D. S. Herson (1994), 'Microbiology and Biodegradation', *in*. Baker, K. H. and D. S. Herson (eds.) *Bioremediation.* McGraw-Hill, Inc., New York, pp.9-60.

Fujie, K., H. Y. Hu, H. Tanaka, K. Urano, K. Saitou and A. Katayama (1998), 'Analysis of respiratory quinone profile in soil for characterization of microbiota', *Soil Sci. Plant Nutr.,* 44, pp.393-404.

Hasanudin, U., M. Fujita, T. Kunihiro, K. Fujie and T. Suzuki (2004), 'The effect of clam (*Tapes philippinarum*) on changes in microbial community structure in mesocosm of tidal flat sediment, based on quinone profile', *Eco. Eng.,* 22, pp.185-196.

Hu, H. Y., K. Fujie, H. Nakagome, K. Urano and A. Katayama (1999), 'Quantitative analyses of the change in microbial diversity in a bioreactor for wastewater treatment based on respiratory quinones', *Water Research* 33(15), pp.3263-3270.

ISCC (2011), "Sustainability Requirements for the Production of Biomass", *ISCC 11-03-15 v2.3-eu.* Köln, Germany: International Sustainability & Carbon Certification (ISCC).

Katayama, A. H. Y. Hu, M. Nozawa, H. Yamakawa and K. Fujie (1998), 'Long-term changes in microbial community structure in soils subjected to different fertilizing practices revealed by quinone profile analysis', *Soil. Sci. Plant Nutrision,* 44, pp.559-569.

Tóth, G., V. Stolbovoy, and L. Montanarella, (2007), 'Soil Quality and Sustainability Evaluation, an Integrated Approach to Support Soil-Related Policies Of The European Union', European Commission, Directorate General Joint Research Centre, Ispra, Italy: Institute for Environment and Sustainability.