The Economics of Ecosystems and Biodiversity: Promoting Biodiversity and Sustainability in The Agriculture and Food Sector Through Economic Valuation

Deliverables Report:

2.2 Technical Document on Methodologies or Model to be Applied

Working Paper

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Cacao Agroforestry System: An Overview Evaluation and Valuation Methods and Tools

1.1 Introduction

This report describes tools and methods of valuation and evaluation to be applied in this study in order to estimate the impact and dependence of production, processing, distribution, and consumption activities of cocoa agroforestry on supporting ecosystem and their services, and on people welfare. The ecosystem is a principal segment of the asset base of a country or region. It includes human and social capital, produced capital, and natural capital.

This report discovers the way to conduct evaluations, distinguish between (and giving examples of) methods for the economic valuation of ecosystem services and disservices in both monetary and non-monetary terms. It also explores tools and techniques of modelling needed by this study.

1.2 The Need for Valuation of Potential Cacao Agroforestry System

There is a lot of ecosystem service reliance and effect of the cocoa agroforestry system that are not completely captured in the market. Dependency and impacts in monetary terms can be measured by economic valuation tools. They also can make them more comparable to other things we value.

However, economic valuation is unable to give a full picture alone; additional evaluation techniques are needed to help the understanding of the relative merits of different policies, actions, and strategies. Different stakeholders make different policies and production decisions that involve trade-offs for the economy, the environment, and various stakeholders. The data needed to evaluate such as trade-offs are provided by economic valuation methods. To understand the benefits are worth the costs not only to society as a whole but also to groups of producers and consumers, we will use evaluation techniques. Meanwhile, they are also assessing the wider social, economic, and environmental impacts of decisions.

Agriculture relies on ecosystem services as inputs. It also provides many ecosystem services. Stages that need to be got through by cocoa produced by farmers are land clearing and preparation, planting, growing, harvesting, product preparation for the consumer market, consumption, and final waste disposal. Every stage generates several economic impacts. These impacts are generated in the form of income for producers, wages for employees, tax revenues to the government or subsidies from the government, the possibility of importing inputs and exporting outputs, etc. Several impacts are captured through market transactions or financial resources from one agent in society to other. Meanwhile, the positive and negative impacts on the economy and wellbeing are not assessed.

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1.3 Methods for the Economic Valuation of Ecosystem Services in Cacao Agroforestry System

Ecosystem services are defined as the direct and indirect contributions of ecosystems to human well-being" (Kumar, 2012). Wellbeing is not only about income, but also includes security, basic material for the good life, health, good social relations, and freedom of choice and action. Changing in ecosystem services e.g., due to changes in agricultural practices, anthropogenic factors and climate change will affect human wellbeing.

Expressing the value of ecosystem services in monetary units is an important tool to raise awareness and convey the relative importance of ecosystems and biodiversity to policymakers (De Groot, 2012). Before economic valuation can be applied, the performance or availability of ecosystem services has to be measured in biophysical terms (available in section 2.1).

We will perform our analysis for 30 years to capture longer-term economic uncertainties and will conduct 5-step analytical framework, as follows

1) Identification of the full suite of ecosystem services which are meaningful in the context of this study, by making an inventory of all possible ecosystem services from cacao monoculture and agroforestry,
2) Preparing a short-listed of several services for analysis, based on consultation with experts, local stakeholders, and literature reviews,
3) Quantification of the service-providing units and their relationships with the provision of services.
4) Conducting economic valuation of each ecosystem services.
5) Extrapolating results and examining trade-offs.

This study will determine the total economic value (TEV) of the tropical forest Ecosystem and evaluate the consequences of cacao agroforestry expansion scenarios. A dynamic simulation model would be applied to evaluate the TEV of particular areas over the period 2021 to 2050.

Tables 1 and 2 indicate potential ecosystem services and disservices due to the cacao agriculture system. In some cases, the state of ecological knowledge and the data availability allow using some direct measures of services, while in other cases it is necessary to make use of proxies.

Table 1. Potential ecosystem services and valuation approaches

Ecosystem Services	Valuation approaches	Measurement	Data required
1) Provisioning			
• Food (cacao, fruits)	Direct market price	Profit from cocoa and fruits	Prices and quantities of the cocoa/fruits inputs and cacao/fruits
• Raw materials (timber, non-timber products)	Direct market price	Profit from raw materials	Prices and quantities of the raw materials' inputs and raw materials
2) Regulating			

• Water flow regulation	Substitution cost	• SWAT model • Correlating impact of frequencies reduction flood and drought on yield and harvest area	SWAT model inputs (soil map, land use map and climate data)
• Climate regulation/ Carbon storage	Direct market price	Social cost of carbon	Net carbon sequestration from agroforestry, social cost of carbon
• Soil biodiversity	Replacement cost	Cost to replace natural decomposer with "artificial" decomposer or additional organic fertility	Soil microarthropods, soil fungi, and soil microbes abundance and cost of replacement
• Soil nutrient loss through erosion	Replacement cost	• SWAT model • Cost of nutrients (N and P) and soil carbon loss	SWAT model inputs (soil map, land use map and climate data)
• N and P loads	Cost of water treatment	• SWAT model • Costs required to improve water quality to a certain quality standard	SWAT model inputs (soil map, land use map and climate data)

Table 2. Potential ecosystem disservices and valuation approaches

Disservices	Valuation approaches	Measurement	Data required
Change in cacao provisioning	Direct market price	Profit from cocoa	Prices and quantities of the s inputs and cacao
Increasing pest	Production Function	Change in production value due to change in soil nutrient	Quantities of inputs and outputs in physical units. Prices of key outputs and inputs
Competition of nutrient and water			

Suppose there are three potential scenarios of cocoa production expansion including business as usual (BAU), indexed by $j = 1, 2, 3$, which will be implemented during the planning horizon $t \epsilon$ [0,T]. The TEV for the individual scenarios j can be determined by aggregating the monetary value of ecosystem services indexed by $e = 1, 2, \dots, S$ as follows

$$B_{j,t} = \sum_{e=1}^{S} B_{e,j,t} \tag{1}$$

where $B_{e,j,t}$ is the monetary value of ecosystem services type e provided under scenario j at year *t*. Valuation approaches shown in Table 1 will be employed to estimate the $B_{e,j,t}$.

1.4 Overview of Evaluation Methodologies

The previous sections focused on the implementation of particular valuation techniques that produce monetary estimates of the external costs and benefits of cocoa agroforestry systems and their dependencies on ecosystems. These estimates are of great value to either public policymakers or private investors.

Nevertheless, questions of equity in food production, things such as awareness and education in promoting health practices, and widening contribution to the Sustainable Development Goals (SDGs) need to be considered. Furthermore, links across the economy, between the cocoa agroforestry and other sectors, as well as the sector contribution to economic growth and employment stay being important considerations. To help us understand the way cocoa agroforestry systems functions in light of these broad goals, Cost-Benefit Analysis (CBA) will be applied.

CBA allows to compare the potential benefits and costs between business as usual (Monoculture & Simple agroforestry = SAF) and Complex agroforestry (CAF) scenario. Although many studies have shown that the latter outperforms the former, this study would like to identify the best farm-level practices which can achieve cocoa agroforestry both economically viable and environmentally desirable. This condition is challenging because decision-makers will face the dilemma of balancing cocoa production and environmental impacts due to farm management changes.

Suppose the two scenarios i.e. business as usual (BAU) and CAF, indexed by $j = 1, 2$, which will be implemented during the planning horizon $t \in$ [0,T]. Decision-makers would like to identify scenario j which maximizes wellbeing indicated by increasing cocoa production and outcomes for natural, human, and social capital. Therefore, decision-makers consider the present value of net benefits generated by scenario j, $PVNB_j$, as follows

$$PVNB_j = \sum_{t}^{T} \frac{1}{(1+r)} B_{j,t} - C_{j,t} \quad (2)$$

$C_{j,t}$ is the summation of production costs for the implementation of scenario j at year t, $P_{j,t}$, and environmental disservices resulted by scenario j at year t, $L_{j,t}$ i.e.,

$$C_{j,t} = P_{j,t} + L_{j,t} \quad (3)$$

and $r > 0$ indicates the social discount rate.

The main challenge for the calculation of the stream of benefits and costs above is not all benefits and costs are marketed. Some benefits that contribute to human well-being do not have a price attached to them and are therefore neglected in normal market transactions (Freeman 2003; Heal et al. 2005). To estimate $B_{e,j,t}$ and $L_{j,t}$ various economic valuation techniques (see Tables 1 & 2) are required.

For the implementation of the CAF scenario, five policy interventions (see report 1.2) are considered. It is interesting to calculate the cost effectiveness of each intervention option, by comparing the net benefits of the CAF scenario with the total costs of the intervention option. The total costs include investment, operational costs, and government expenditures (e.g., upfront agroforestry costs, agricultural extension services, and redirected subsidies) during the time horizon. Indeed, cost effectiveness of intervention options relative to BAU can be compared.

Furthermore, the Return on Investments (ROI) of each intervention will be calculated. ROI is one of commonly used financial metrics to measure the performance of investment. Here, the ROI is a percentage that represents the net benefits received from CAF investment over the time horizon.

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1.5 Modelling Tools and Techniques

In the previous sub-chapter explained how to evaluate and evaluate the impact of cocoa agroforestry. This subchapter will explain Modelling tools and techniques that will be used in this research.

1.5.1 Land Use and Biophysical Models

Biophysical models help planners decide how to manage the land and draw long-term plans for development, including the location of different activities and their impact on land, ecosystems, and people. Such models can be a key input into the valuation of ecosystem services related to agriculture. The approach to measuring aspects of natural capital in this study uses several models, including Spatial Planning Tools and Ecosystem Services Models such as The Soil & Water Assessment Tool (SWAT), TerrSET, and Soil Analysis.

1. Spatial Planning Tools

a) Multivariate and Cluster Analysis

This study will be carried out at centres of the potential cocoa plantation and production, either in the monoculture system on privately owned areas outside forest territory or within the forest areas with an agroforestry system. In the early stage, cacao typology map will be developed based on spatial considerations as our main concerns. The map will cover various biophysical aspects (e.g., percentage of area with gentle topography, proportion of cacao plantation area, and cacao planting patterns), social aspects (e.g., education level and population), and/or economy aspects (e.g. percentage of non-permanent house types, percentage of agricultural lands per region), institutional (presence or absence of institutions regulating cacao management), infrastructure, (e.g. road accessibility to cocoa market centres), as well as politics. This study would also develop agroforestry typology using cacao productivity per region as its basis if the data are available. Furthermore, we will employ a multivariate method together with the cluster analysis in order to develop the cacao typology map quantitatively.

b) Markov CA and Multi criteria evaluation

The spatial analysis will then be focused on describing the dynamic change of land cover, which would particularly affect the agricultural system. Hence, we divide this analysis into four main stages i.e., a) land cover change analysis, b) generating change transition matrix (in terms of area change), c) developing cacao suitability map, and d) forecasting land cover to a certain timespan. In order to do so, this study utilizes time-series land cover data from the last three decades (1990 – 2020). The timespan of the land cover prediction is thirty years; therefore, the results would exhibit a land cover map of 2050.

The land use prediction would be modelled using TerrSet software developed by Clarck University. The Land-use Change Modeler (LCM) in TerrSet (formerly known as IDRISI) software was originally designed to manage biodiversity influences and to analyze and forecast land use and land cover changes. This model is based on **Artificial Neural Network** (ANN), **Markov chain matrices,** and **transition suitability maps**, generated by **training multilayer perceptions** (MLP) or **logistic regression**. This model predicts the land use and land cover changes from the thematic raster images having the same number of classes in the same sequential order. Land-use change modeler involves several steps

(1) change analysis, (2) transition potential and determination of explanatory variables, (3) change prediction, and (4) model validation.

Change analysis could be defined as charting gain and losses between time 1 and time 2. It is also estimating net changes, persistence, and specific transition of land cover information in both map and geographical maps. This is important to identify the dominant transition from one class to another. All the dominant transitions are then grouped and targeted. The spatial trend of change provides the trend in the form of a map, with the best fit polynomial trend surface adhering to the pattern of changes.

The next step is transition potential modelling and driving forces determination. The first is transition potential determines the area of change. Land cover transition can be grouped into sub-models, if it assumes that for each transition, the underlying drivers of changes are the same. The second is selection of explanatory variables (or drivers) responsible for land use and land cover changes (suitability map) as described in Figure 2. For instance, topographic, proximity, distance, water channel, and distance to road factors affecting urban sprawl. The weight must be resolved in the training process before the system is utilized for prediction.

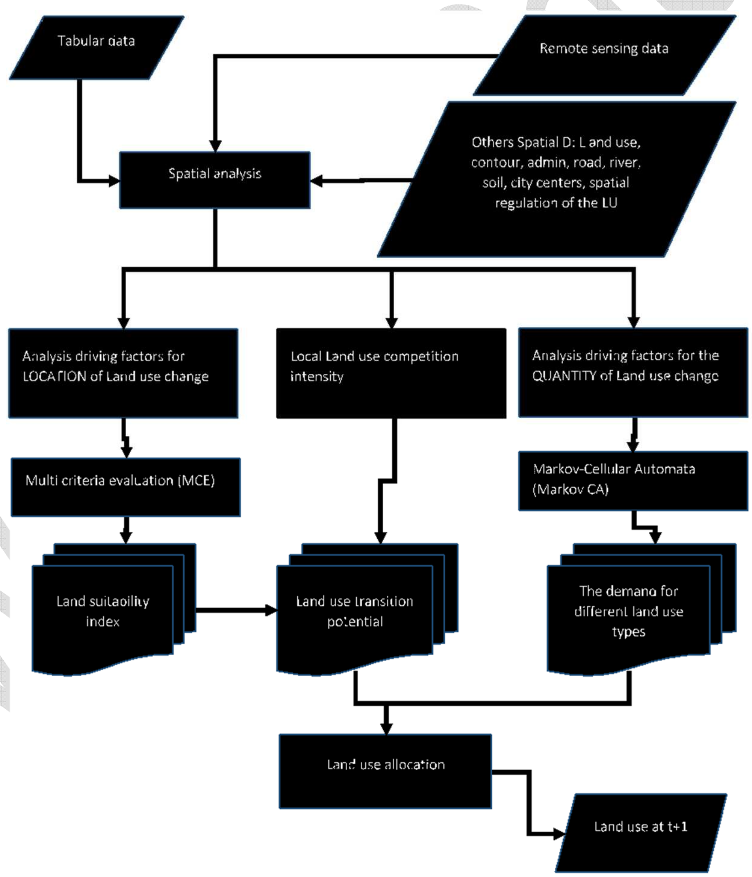

Figure 1. General structure of the local land use competition cellular automata (LLUCA, after Yang et al. 2016)

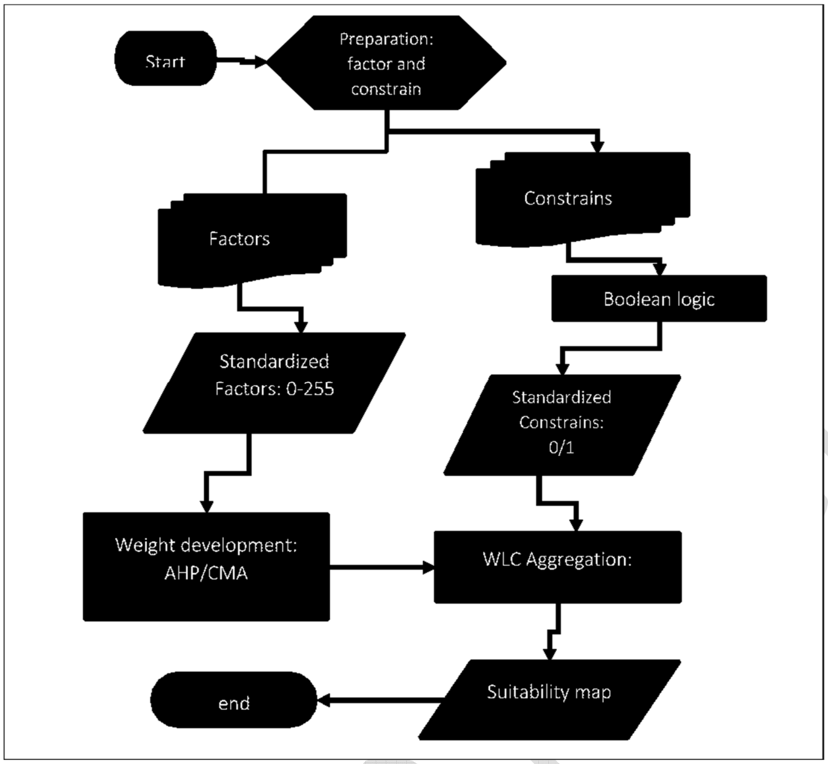

Figure 2. Steps for developing a suitability map

Land cover modeler subsequently enters the next step, Change Detection. Change prediction is the last step based on the Markov chain and using the historical rate of change and the transition potential maps. The model can forecast the future land uses by using the transition probability. The probability map is generated using multilayer perception, provide a probability estimation that each pixel will either be converted into another land cover type or persist be adjusted during annual time stop.

The last step is predicting the future land use. Land change modeler produces 2 kinds of predictions: (1) hard prediction and (2) soft prediction. A hard prediction produces a predicted map base on a multi-objective land allocation (MOLA). Soft prediction determines the probability of pixel changing to another land category by producing a vulnerability map, where the value from 0-1 is assigned to each pixel.

Model validation is required to assess the accuracy, by comparing the simulated map and the actual map or land use. Model validation method may use Kappa statistics and Relative operating characteristics (ROC). For predicting of a certain land use (e.g. cacao plantation) in 2050, the general step would be carried out as outlined in Figure 3.

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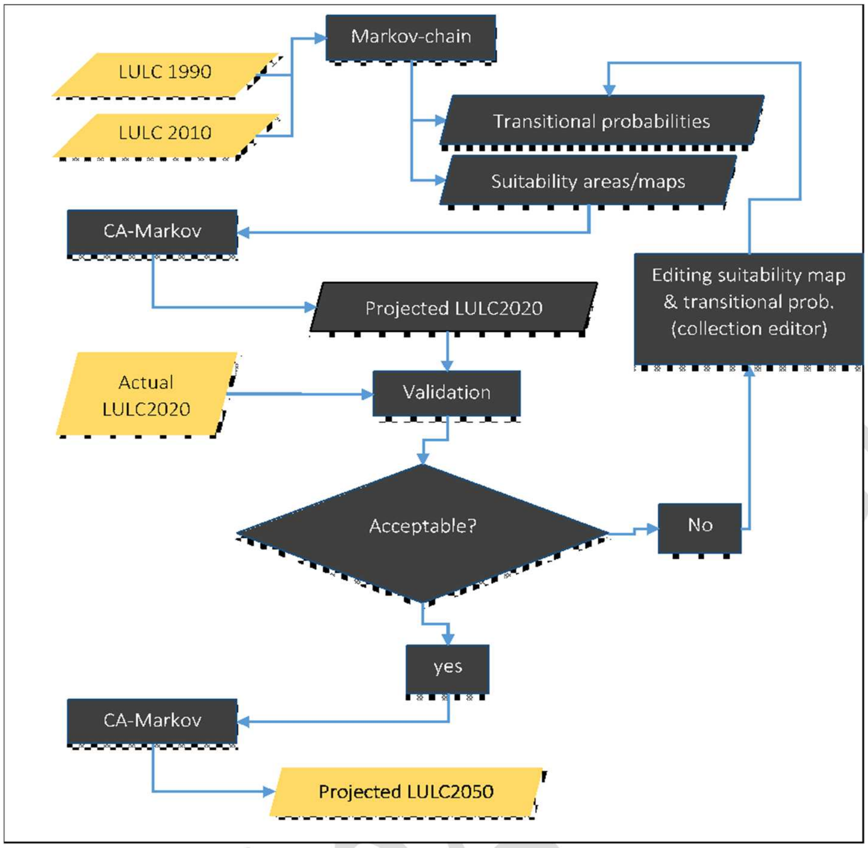


Figure 3. Flow-chart of Markov-CA Modelling for predicting LULC in 2050

To employ Cellular Automata (CA), a suitability map is required for each class, as a prerequisite.

This suitability map is derived from the MCE analysis by combining several criteria to form an evaluation index. In the MCE method, various variables are aggregated using weights based on the knowledge of the experts about the interactions and variables that affect LULC. Suitability for each land cover is determined using a number of factors, namely: 1) distance from the road, 2) distance from the river, 3) slope, 4) elevation, 5) distance from the settlement, 6) rainfall, 7) population density, 8) soil type.

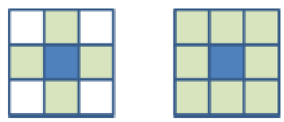
The development of this suitability class requires the following steps:

[1] Identification and development of criteria (Determination of factors and constraints (constraints))
[2] Standardization of factor values with fuzzy functions
[3] Converts factors to standard values (e.g., 0-255)
[4] Calculation of weight (quantitative or semi-qualitative: AHP with eigenvector values)
[5] WLC (weighted linear combination)

Prediction of land-use change in the future will be carried out by using the concept of transition probabilities of the Markov chain (Markovian chain transition probabilities) combined with the concept of change using 2-dimensional Cellular Automata rules following Conway's Game of Life concept. This 2-dimensional CA is depicted in the form of a 3 x 3 square template. The concept of neighborliness which is commonly used is the concept of 4 neighbors which was initiated by Von Neumann or using 8 neighbors initiated by Moore as presented in Figure 4.

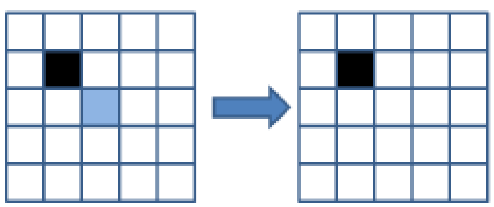
This Conway concept can be used to predict changes in land cover. Each pixel describes a state (alive) or dead (dead). Living cells can turn into death (events of death) or dead cells can turn into living (birth events) or living cells can remain alive. There are four basic rules in this change (see Figure 5):

1) Living cells will die if they have less than 2 living neighbors (lonely),
2) Living cells will turn dead if they have more than 3 living neighbors (overpopulated),
3) Dead cells will become alive if they have 3 living neighbors,
4) Otherwise, nothing changes.

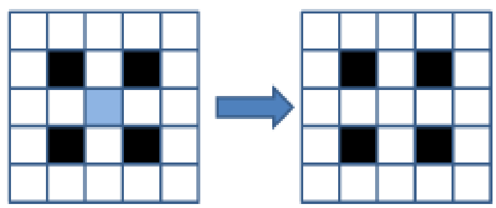


(a) (b)

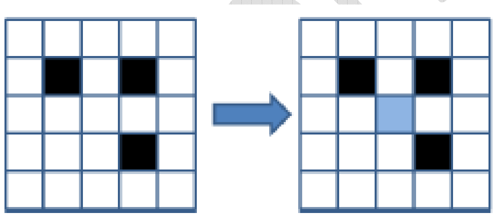
Figure 4. Neighborhood Concepts: (a) Von Neumann & (b) Moore



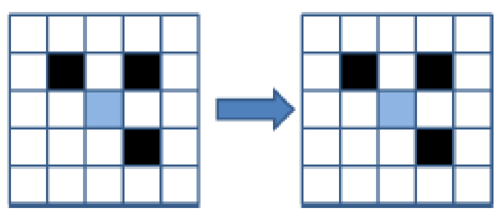
a) Living cells will die if they have less than 2 living neighbors (loneliness)



b)) Living cells will turn dead if they have more than 3 living neighbors (over populated)



c) Dead cells will become alive if they have 3 living neighbors (birth)



d) no-change

Figure 5. The rule of Conways's Cellular Automata

2. Ecosystem Services Model

a. The Soil & Water Assessment Tool (SWAT)

Soil and Water Assessment Tools (SWAT) is a computationally efficient physical model developed by J. G. Arnold (Arnold et al., 1998) for the USDA Agriculture Research Service (USDA-ARS) from several ARS (Agricultural Research Service) models (Neitsch et al., 2015). SWAT works at a watershed scale and allows several different physical processes to be simulated in a watershed for long-term periods, such as the hydrological cycle, plant growth, pesticide transport, erosion and sedimentation, and nutrient cycle (Neitsch et al., 2015; Zhang et al., 2019). SWAT is a semi-distributed model that divides a watershed into several sub-basin and then divides each sub-basin into several hydrological response units (HRUs). The sub-basin and HRU are used to explain the spatial heterogeneity of the physical processes in the watershed system for each combination of land use features, vegetation, soil, and topography (Zhang et al., 2020). Also, sub-basin and HRU help increase simulations' accuracy because heterogeneity in land use, soil types, and topography have different impacts on physical processes (Wang et al., 2019)

In this study, the output of the SWAT model can help stakeholders in assessing the impact of land management on water quantity and quality, nutrient leaching, and erosion and sediment transport, especially for complex watersheds with features that vary spatially and temporally but have limited data availability due to lack of monitoring data in Luwu Utara (Arnold et al., 1998; Dash et al., 2020). No matter what type of problem is studied with SWAT, hydrological processes are the driving force behind everything in the watershed system. The main hydrological processes simulated with the SWAT model include evapotranspiration, surface flow, lateral flow, and baseflow, calculated based on the water balance equation (Zhang et al., 2019).

$$SW_t = SW_0 + \sum_{i=1}^{t} (P - Q_{SRO} - E_a - Q_{SSRO} - Q_{BFO}) \quad (4)$$

where SW_t is the final condition of soil moisture, SW_0 is the initial condition of soil moisture, P is precipitation, Q_{SRO} is surface runoff, E_a is actual evapotranspiration, Q_{SSRO} is a lateral flow, Q_{BFO} is base flow or groundwater flow, t is time in days, all units are in the metric system (mm).

From this equation, the hydrological components related to ecosystem services are surface runoff, lateral flow, and baseflow as a source of fresh water supply. The surface runoff and rainfall from this equation are also used to calculate soil erosion based on the Modified Universal Soil Loss Equation (Neitsch et al. 2015). The nutrient component of the SWAT model includes inputs from agriculture, transport with surface runoff and groundwater, consumption by plants, and mineralization processes occurring in the soil. Nitrogen and phosphorus are mainly removed by soil erosion and transported with sediments to rivers. SWAT considers the amount of organic and mineral nitrogen and phosphorus transported with sediment to the river by loading function (Neitsch et al. 2015).

Pre-processing, model running, analysis of sensitivity, and accuracy and uncertainty test are the four stages of the SWAT simulation. Spatial data needed to run SWAT model are digital elevation model (DEM) from Geospatial Information Agency which is available with a spatial resolution of 8 meters,

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land cover derived from image interpretation, soil map with scale 1: 50,000 from Indonesian Center for Agricultural Land Resources Research and Development, land cover and soil physiochemical attribute from the field survey and literature, and daily meteorological observation data from Andi Jemma Meteorological Station in Luwu Utara. If the discharge and sediment data from Public works agency (Dinas PU) or BBWS is available, SWAT output will be calibrated and validated in a selected period.

In this study, SWAT is also used to simulate the change in the surface water availability and soil erosion because of agroforestry scenarios in a selected catchment and the change in water quality that related to the fertilizer application because of agroforestry scenarios which affect the content of nitrogen, phosphorus, and sediment in rivers. Change from monoculture to agroforestry cacao will involve change in crop and soil parameters such as leaf area index (LAI), rooting depth, soil organic matter, infiltration rate, and soil physiochemical characteristics. Data related to the change of crop and soil parameters are adapted respectively from soil sampling and previous literature such as Gusli et al. (2020) and Saputra et al. (2020).

b. TerrSET Carbon Stock and Sequestration

TerrSET software is also used to estimate carbon stock and sequestration. The volume of carbon is calculated based on the literature and various reports of government institutions or those that have been published by other institutions accompanied by the results of field observations. The amount of carbon stored in a land parcel depends on the size of four primary carbon sinks: aboveground biomass, belowground biomass, soil organic matter, and dead organic matter. Aboveground biomass is all the living biomass above the soil including the stem, stump, branches, bark, seeds, and foliage. Below ground biomass is the living biomass of roots underground. Soil organic matter is the largest carbon pool on land and is made up of the living biomass of micro-organisms, fresh and partially decomposed residues, and humus. Dead organic matter, or detritus, is typically made up of leaf litter and other organic matter mixed with soil. A fifth, optional carbon pool is the harvested wood products (HWP) pool, specified by parcel, which includes the amount of carbon stored in the wood that is harvested from a forested land parcel, the frequency of harvest, and the decay rate of these wood products. It is assumed that the carbon stored in HWP is released as the product decays.

c. Soil Analysis

Soil quality to be studied is soil physical properties (bulk density, porosity, and water retention), soil chemical properties (C-organic, N-total, P-available, and P-total), soil biology (soil fauna, total microbial and total fungi). The tools used for soil sampling are ring sample, global positioning system (GPS), hoe, soil fork, soil thermometer, meter, ruler, and label. Tools for total microbial and soil fungi analysis were Laminar Air Flow (LAF), autoclave, oven, incubator, vortex, shaker, stirrer, microtip, micropipette, scales, Bunsen, test tube, petri dish, and Erlenmeyer. The tools for analyzing soil chemical properties are destruction tools, macro Kjeldahl tools, distillation, titration tools, beakers, measuring cups, Erlenmeyer, volumetric flask, UV-VIS spectrophotometer. Tools for analyzing soil physical properties of automatic compressors, pressure plate apparatus, pressure membrane apparatus, and 2 mm sieves.

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The materials used to analyze total microbial and total fungi were soil samples, physiological solution, distilled water, Nutrient Agar (NA) and Martin Agar. The chemicals needed are PA solution (Bray1 & HCl 25%), PB, PC, K2Cr2O7 1 N, ferroin indicator, FeSO4.7H2O 1 N, H2SO4, HCl 0.1 N, boric acid 4%, NaOH 50%, Conway indicator, borax, and selenium mix. The materials used in the analysis of soil physical properties are undisturbed and disturbed soil samples.

Table 3. Summary of Land Use and Biophysical Models

Scope	Models	Objective	Output
Spatial Planning Tools	Multivariate and Cluster Analysis	Development of Land Typology	Land use baseline (2020)
	Markov CA	Land cover change detection and prediction	Land use 2050
	Multi-criteria evaluation	Land suitability	Land suitable for cacao production
Ecosystem Services Model	SWAT	Water quality: nutrient pollution	Nutrient (nitrogen and phosporus) transported to the river and groundwater
		Water quality: sedimentation	Sediment transported to the river
		Water quantity (water yield)	Annual and seasonal surface and groundwater water yield
		Erosion and land degradation	Amount of eroded soil in each land use
		Soil nutrient	Amount nutrient stored in the soil
		River discharge	Annual and seasonal river discharge related flood prevention
	Soil Analysis	Soil quality and biodiversity	Soil physics, soil chemistry, and soil biodiversity abundance
	TerrSET	Carbon stock and sequestration	Mass of sequestrated carbon in a landscape

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1.5.2 Human Capital Analysis

The human capital analysis will be conducted through descriptive statistic and labour productivity analysis approaches. The methodology is as follows:

Descriptive Analysis

Descriptive statistics, in short, help describe and understand the features of a specific data set by giving short summaries about the sample and measures of the data. The most recognized types of descriptive statistics are measures of center: the mean, median, and mode, which are used at almost all levels of math and statistics. The mean, or the average, is calculated by adding all the figures within the data set and then dividing by the number of figures within the set. Descriptive analysis in this research will be figured out of skill and knowledge among cocoa farmers.

One method to calculate implicit/opportunity costs or benefits of farmers with social and human capital (or relative moderate/high) compare to farmers with no social and human capitals (or relatively low) is Difference in Difference (DiD).

Table 4. Difference in Difference Method

Farmers Category based on SC	Treatment Groups	Farmers are members of farmer groups or cooperatives
	Control Groups	Farmers are not member of farmer group or cooperatives
Farmers Category based on HC	Treatment Groups	Farmers with relative high knowledge and skills or farmers with relative good health conditions or relative high productivity
	Control Groups	Farmers with relative low knowledge and skills or farmers with relative bad health conditions or relative low productivity

The type of method that will be used depends on the type of data and the state of the sample will be examined. The farmers with differences social and human capitals indirectly created two different treatment groups, where the group of farmers with relatively high social and human capitals and the group of farmers with no or relative low social and human capitals which are referred as control group. With the availability of farmer's data with differences in social and human capitals, then the most appropriate method for evaluating the impact of social and human capital in this case is a method Difference in Difference (DID).

The DID method calculates differences in changes in the value of dependent variables between Treatment Group and Control Group within a certain period of time. Thus, it can be known the impact of a treatment of a bound variable that is being evaluated. Mathematical illustration the DID method is depicted in equation below:

$$DID = (YT_2 - YT_1) - (YC_2 - YC_1) \quad (5)$$

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where $(YT_2 - YT_1)$ is a change in the value of the dependent variable for Treatment Group during the observation period and $(YC_2 - YC_1)$ is a change in the value of the dependent variable for the Control Group during the observation period (Card and Krueger, 1994; Gertler, Martinez, Premand, Rawlings and Vermeersch, 2011).

1.5.3 Value Chain Analysis

The agrifood value chain can be simplified by Figure 6. In this study, the value chain method will be applied to map the chain of cacao commodity in terms of the flow of products and actors involved in the value chain starting from producer level (farmers) to consumer level and to identify which actors provide the biggest value-added in the value chain. Since this research focuses on cacao beans, the value chain analysis will be conducted until processor level and will not involve retail and consumer levels

The mapping activities can be divided into (1) mapping of the actors involved in the value chain, (2) mapping the sales volume of each actor, (3) mapping the product value along the chain, (4) mapping the proportion of costs incurred by each actor along the value chain, and (5) mapping the flow of information and technology transfer. After the mapping conducted, the next analysis will be focused to examine the performance of the chain (i.e, farmer's share and margin) and policy interventions needed to improve the performance of the chain.

Figure 6. Agrifood Value Chain

Source: Stringer (2015)

In order to depict the value chain framework as outlined above, we will conduct three main activities: (1) interview with the actors along the value chain, (2) focus group discussions and (3) simulations related what policies that can support the value addition in the cocoa value chain and its sustainability.

Interview will be conducted by using a structure questionnaire with actors throughout cacao value chains, as well as those involved in policy relating to the cacao system. The interview will be focused to current practices conduct by actors along the cacao value chain, challenges and opportunities face by them. The information gathered from the interview will be collated and analysed as the basis for the next analysis, i.e., the simulations of the policy interventions needed to improve the sustainability of cacao value chain.

Focus group discussion will be conducted to get more insight related to the policy interventions that would lead to improve the functioning of cacao value chains that *support economy, biodiversity, and support livelihoods of farmers.*

Data analysis will be conducted using descriptive statistics analysis and will be presented in the form of tables and figures.

1.6. Computable General Equilibrium (CGE) models

The Data and Model

Data use in this study especially for constructing the CGE modeling was Input-Output table at national level 2016, Indonesian Social Accounting Matrix 2008, and estimation parameters for doing the simulation which is gathered from previous studies. In order to construct the CGE model with the supporting data, some arrangements through certain steps have been done. The arrangement of basic data begins with the selection of data aggregation, e.g., number of commodities, industry, household (10 groups), and origin of commodity (imported or domestic), amount and type labor (skilled or unskilled), and production factors.

In this study's CGE model, the number of commodities used is 185 sectors which were gained from the aggregation of 185 sectors Table I-O of year 2016. The focus of the sectoral aggregation represents the cocoa sector and other related sectors. We also link the regional extension block in the model and incorporate the 2016 Inter Regional Input Output Table (IRIO) published by the Central Bureau of Statistics (BPS-Indonesia). The IRIO Tables consist of 17 and 52 sectors for 34 provinces and 6 regions (islands). By utilizing the top down CGE model, we can further elaborate the possible impacts of CAF in South-Sulawesi.

The CGE model used is WAYANG-ORANI model which is the combination from WAYANG model (Wittwer, 1999) and ORANI-G model (Horridge, 2002). ORANI-G is an applied general equilibrium (AGE) model of the Australian economy which has extensions to the basic model including systems of government accounts, and regional breakdowns of model results and confines to comparative-static analysis. The model has already served as the basis for models of other countries including Indonesia. Otherwise, WAYANG model is an Indonesian CGE model that has a strongly agrarian economy in the short to medium term. Data is processed using the GEMPACK program.

The theoretical structure used in WAYANG-ORANI consists of a non-linear equation system on the labor demand, primary input demand, intermediate input demand, composite input demand, composite output of industry, demand on investment goods, household demand, export and other end-user demands, market-clearing equation, consumer prices and indirect tax, GDP from revenue and expenditure sides, rates of return and waging index, investment equation, capital, and debt

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accumulations. It is noticeable that there is a relationship between sectoral economy and macro-economy. The relationship among variables in the macro-economy can be clearly seen in Figure 7.

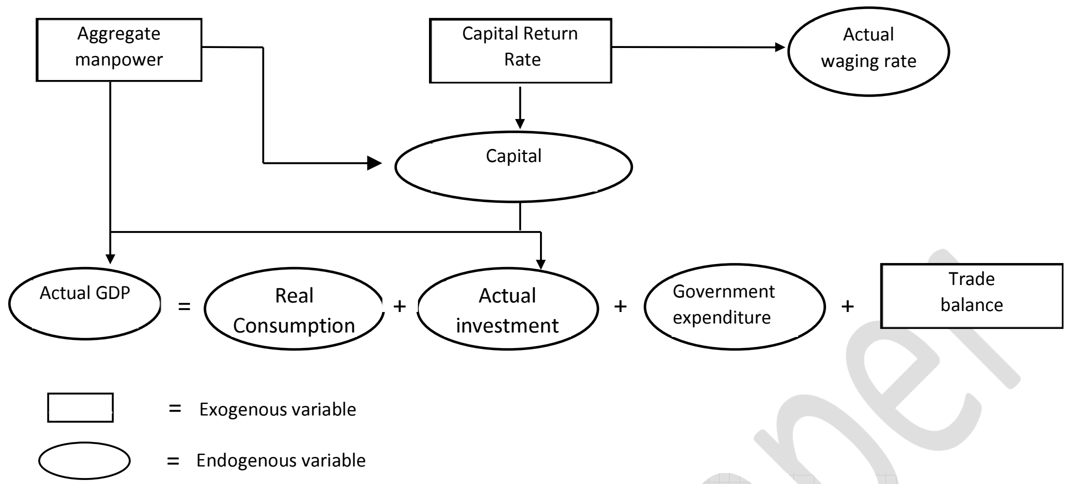

Figure 7. The Relationship among Macroeconomic Variables in the WAYANG-ORANI Model

The relationship among variables in macro-economy is changeable according to the objective of the research. The effect of change in sectoral policy could also be seen on other sectors and macro-economy variables. The magnitude of change occurring on every variable could then be calculated by CGE model. The solution procedure model is determined by making the involved equation linear, i.e., by stating that all variables are in their percentage change. Linearized equation consists of coefficients equivalent to non-linier equation. The mathematically derived version of this nonlinear equation to linear and the methods to update the formula are further discussed in Dixon *et al.* (1982) and Horridge *et al.* (1993). The model is organized into 18 blocks as follows:

1. Demand for labor
2. Demand for primary factors
3. Demand for intermediate inputs
4. Demand for composite primary factors and intermediate inputs
5. Commodity composite of industry output
6. Demand for investment goods
7. Household demands
8. Export and other final demands
9. Demand for margin
10. Purchaser prices
11. Market clearing condition
12. Indirect taxes
13. Gross domestic product (GDP) from the income and expenditure sides
14. Trade balance and other aggregates
15. Rates of return, indexation
16. Investment–capital accumulation equation
17. Debt accumulation equations
18. Regional extension

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2. Simulating Alternative Policies

Simulation method is used in order to see the impacts of our cacao agroforestry system on the national macroeconomic performance, sectoral economy, and household income distribution. The simulations are simplified to become four simulations as follows:

- Simulation 1 constitutes Covid 19 Scenarios highlighting the decreasing productivity of agrifood and non-agrifood sectors and decreasing export demand,
  - Agricultural productivity data will be computed based on historical data in 2020-2021 and export demand was calculated from Export Value Index (BPS) in 2020-2021,
- Simulation 2 refers to Sim 1 + Climate Change impacts on Yield from DEWI Model (IFPRI, 2019) and labour migration from urban to rural areas due to the social mobility restriction during pandemic,
- Simulation 3 refers to Sim 2 + yield impact of Complex Cacao Agroforestry with Multipurpose Tree and Shrub -MPTS by 2050
- Simulation 4 refers to Sim 2 + yield impact of Simple Cacao Agroforestry with Monoculture by 2050

Some of the limitations of the model include: (i) as the model does not have an environmental block, hence the national targets of Low Carbon Development initiative and COVID green package via net zero target emission could not be assessed directly; (ii) This CGE model is comparative static in nature. It has no explicit treatment of timeline and thus compares one equilibrium state with another. In the assessment, the model is only able to provide answers on the "What if" CAF is implemented? In detail, this is undertaken by applying changes in the yield shock of cocoa due to CAF in the model and obtaining new equilibrium. The impacts of CAF are described as the effects of the shock with all other things held fixed. As a further consequence of the comparative static CGE model, we are only able to perform the Short Run and Long Run analysis of CAF based on closure modification (Fixed versus Mobile factors of production). Closures allow us to do simulations in different environments. For instance, it would be sensible to assume that producers cannot immediately change their capital stocks, and that rates of return will change in response to CAF. In the long run, however, capital stocks and labor will be mobile and the price of both production factors will adjust to the economic shock. It is important for the closures to reflect the details of the macroeconomic theories.

This CAF assessment by using CGE model is not intended to become a standalone analysis. In the scenarios, we assume that CAF and the improvement in the environmental system will induce cocoa productivity/ yield impact and hence can be assessed as exogenous in the model. We will incorporate the yield impacts of natural ecosystems protection from other modeling e.g., InVEST or economic valuation to be linked with the CGE Model. In detail, the exogenous shocks in each simulation are listed below.

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Table 5. Shocks Introduced in the CGE Simulation

No	Sectors	Output Productivity	Agri Export Demand	CC Yield Impacts	Migration	Agroforestry Yield Impact		
						BAU	SimCacao Agroforestry Expansion to Mono Area	ComplexCacao Agroforestry with MPTS
1	Food Crops	2.30%	-5.36%	-1.28%	-5.00%			
2	Horticulture	2.71%	3.19%	-0.61%	-5.00%			
3	Cocoa	-3.69%	0.60%	-0.61%	-5.00%	Output from other analysis	Output from other analysis	Output from other analysis
4	Other Plantation Crops	0.87%	-5.88%	-0.61%	-5.00%			
5	Livestock	-0.21%	-2.30%	-0.82%	-5.00%			
6	Forestry	-0.02%	-4.30%	-0.80%	-5.00%			
7	Fishery	0.47%	-0.40%	-0.85%	-5.00%			
8	Food and Beverage	0.14%						
9	Tobacco Products	-1.41%						

The results of the simulation will be analyzed using the TEEB Framework as described in the table below. We will also perform the reassessment of the scenarios using the most updated Input-Output Table 2016, published in 2021.

Table 6. Potential Contribution of CGE in the assessment of cocoa agroforestry system

Capital Base Stock	Produced Capital	Capital stock
	Human Capital	Labour productivity
	Social Capital	
	Natural Capital	Land supply
Flows through the value chain	Capital input flows	Include capital and labour (labour disaggregation based on occupation)
	Cacao agroforestry system	Inputs and Outputs 52 disaggregated sectors, focusing on cocoa and related sectors in off farm sectors and supporting services
	Residual flows	None
Outcomes	Economic	Macroeconomic variables (Decomposition of GDP by expenditure and income side, inflation, government budget, real wage, decrease total cost subsidies), Sectoral variables (output, market price at different agents, value added, Decrease Cost of

		other Inputs (seeds, Fuel, Fertilizer, Pesticide), employment, trade.
	Health	None
	Social	Real income at rural and urban household levels Nominal consumption at rural and urban household levels
	Environment	None
Value Chain Impacts		Include various stages of the value chains
Spatial disaggregation		30 regions (Regional gross domestic products, sectors contribution, employment)

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