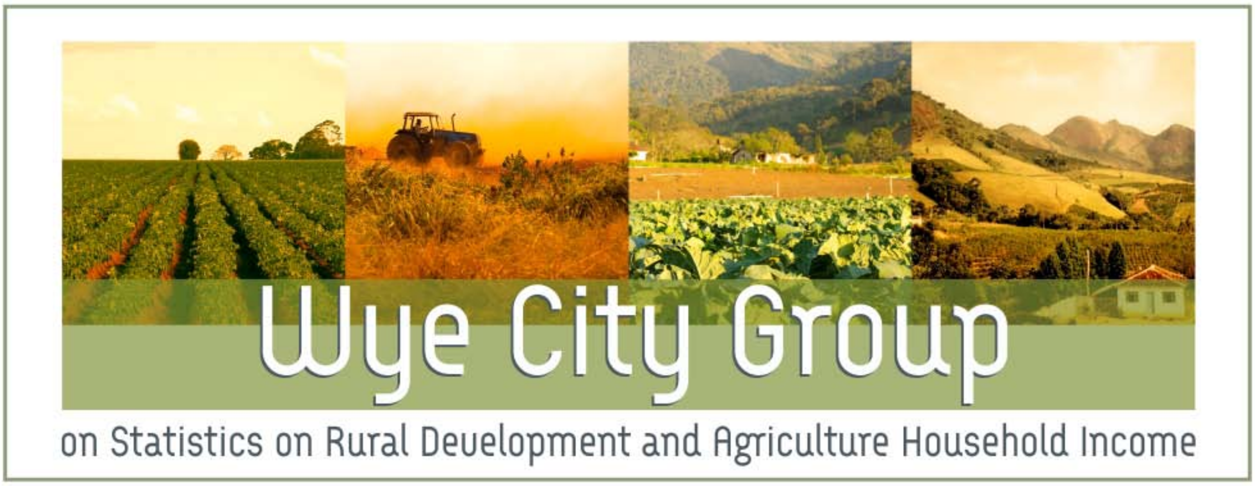

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Farm-Households and Social Relationships: Modelling Issues, and Analysis of Results from a Survey in Sierra Leone

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ABSTRACT:
Farm-household relations represent a central question as related to data collection / processing to provide information on rural development and agricultural-based households income. This issue implies both theoretical and empirical (modelling) facets. In the framework of the SEAMLESS Integrated Project (EU Framework Programme 6), the Farm System Simulator (FSSIM) model was developed. Based on FSSIM a household module is built to take into account farming-household inter-linkages, particularly inflows of extra-farming income by household members, as well as use of (household) family labour, and households (self) consumption of farming outputs. The improvements being developed in the model will allow including issues peculiar of inter-tropical farming systems (FSSIM Africa – provisional title of the new model). Concerning methodological improvements, the last advancements in (Positive) Mathematical Programming as an approach useful to model ex-ante farm-household behaviour under relevant policy scenarios are addressed. The paper includes results of a farm-household survey of Sierra Leone. Results focus on farm-household relations, addressing data collection / processing issues as related to farm-household and village connections.
Keywords: Income, Farming systems, Family labour, Supply modelling.

1. Introduction

Farming system analysis can be either based on empirical data, for instance using data collected for a sample of farms throughout a region or nation, or on quantitative understanding of representative agricultural systems using decision models. Each approach has its own advantages and weakness; they may be either complementary or substitutable. Both have been already used in various contexts to describe current agricultural systems and to provide information to support decision making for improving farm performance. The present paper illustrates via the theoretical presentation of the farm decision model FSSIM (Farm System Simulator) and the discussion of key results from a farm household survey in Sierra Leone, the interest of these kind of approaches for such analysis but also to show their empirical difficulties of adequately capturing (and measuring farm) – household interrelations and decisions.
Section 2 introduces the origins and purpose of FSSIM and how it has been adapted for use in the specific context of developing countries where farm household production and consumption decisions are non-separable. The existence of such non-separability indicates, in fact, the presence of markets imperfection or failures that may have important policy implication. As long as markets are perfect for all goods households are indifferent between consuming own-produced and market-purchased goods and allocate indifferently production between consumption and market sales. However, if there are market failures, a household approach

might be necessary depending on whether the good for which market fails is important in production (Singh et al., 1986). Within this context, the aims of the extended FSSIM model are to describe farm household behaviour given a set of biophysical, socioeconomic and policy constraints and to predict his/her reactions under new technologies, market imperfection and policy changes. This is allowed thanks to the access to reliable rural statistic which expected to not only improve our understanding of smallholders but contribute to enhanced policy making and support.
In section 3 the results from the Sierra Leone Survey are introduced. The data presented here illustrates some of the most common limitations in securing accurate data not only to feed modeling exercises as the FSSIM-Dev but also to better understand the agronomic and institutional limitations which farm households face. Section 4 presents concluding remarks on the key characteristics of FSSIM-Dev and data collection recommendations from the Sierra Leone experience.

2. FSSIM-Dev, Improvements and Extensions

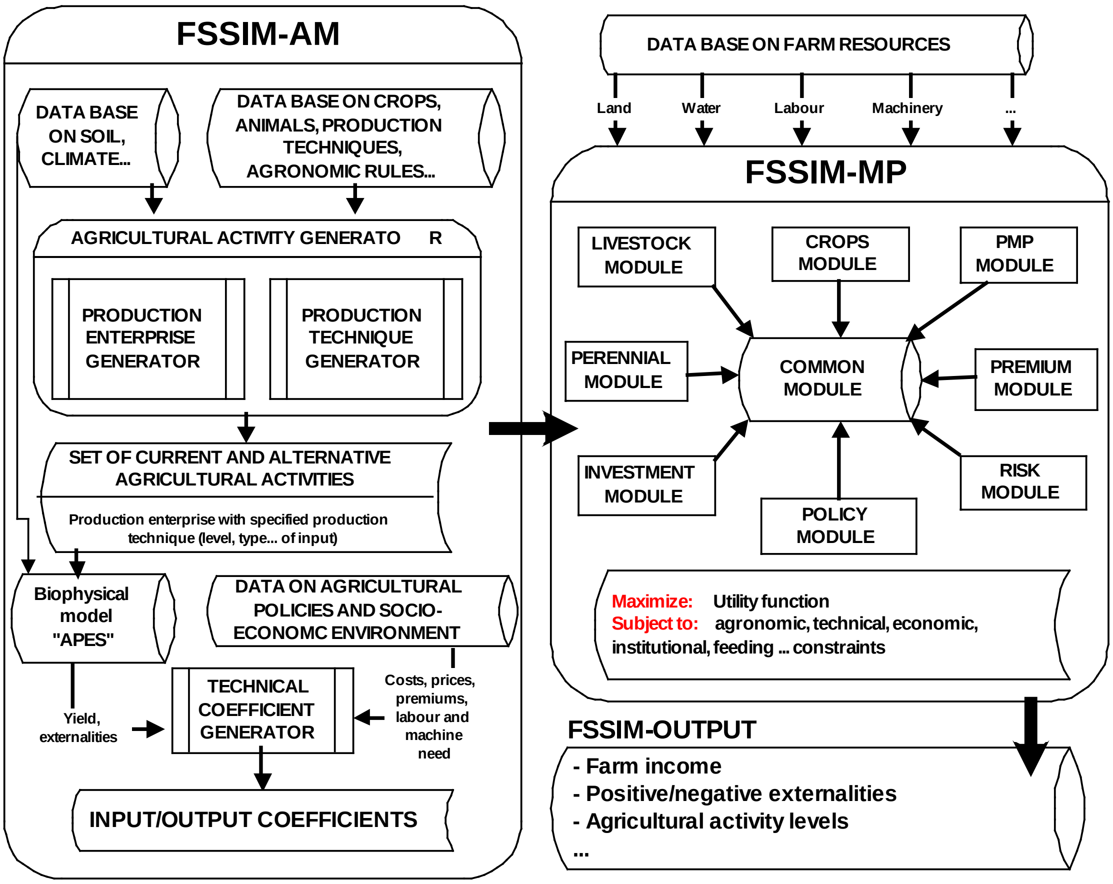
Taylor et al., (2002) have provided a comprehensive review of farm household models by tracing their evolution and uses and summarizing their advantage and weakness. This synthesis was, nevertheless, focused on household models based on an econometric approach, missing those based on mathematical programming (MP). A literature review reveals a wide range of MP farm household models which investigate different questions at various locations. Contrary to household econometric based models which attach a relative importance to consumption utility maximisation, the MP household models attach a relative importance to profit maximisation. The more well-known are: Barbier and Bergeron (1999) built a recursive and dynamic linear programming model which maximizes full income as a proxy for utility where minimum consumption requirements are imposed. Shepherd and Soule (1998) developed a dynamic simulation model that incorporates household needs and financial flows. Okumu et al. (1999) employed a non-linear and multi-objective programming model which optimises a weighted utility function based on three goals (cash income, leisure and basic food production). Holden et al. (2004) take truly advantage of the household decision-making structure of MP models to integrate economic optimization in production and consumption with environmental feedbacks in a non-separable regime. This household model maximizes a welfare function measured as the discounted utility of a certainty equivalent full income. This full income is specified as a function of an expected income based on the probability of expected prices and expected outputs in drought years and years without drought. Farm-household models are often used to analyze the impact of production and consumption decisions on variables of interest, including farm household welfare, market exchange, household resource use and sustainability issues.
The paper presents a generic farm-household model developed within the FSSIM-AFRICA project to assess agri-food and rural policies on the livelihood of farm-households in Africa. This model, called FSSIM-Dev, is an extension of the FSSIM (Farming System Simulator) model (Louhichi et al., 2010a) developed within the SEAMLESS project (Van Ittersum et al., 2008) to predict the impact of agricultural and environmental policies on farm performances across Europe. FSSIM-Dev (Farming System Simulator for developed countries) consists of a non-linear optimization model which optimizes at the farm-household level, with opportunities to simulate the exchange of production factors and production rights between farm-households. It simultaneously solves a set of microeconomic farm-household models reproducing the behaviour of representative households. The use of this farm level modeling approach permits a finer and integrated analysis, capturing the wide heterogeneity among farm households while avoiding aggregation errors (Buysse et al, 2007). FSSIM-Dev is referred to as a static-comparative Positive Mathematical Programming (PMP) which relies on both the general household's utility framework and the farm's production technical constraints, in a non-separable

regime. This section gives a detailed description of the FSSIM-Dev. It was structured as follows: first, an overview of the SEAMLESS FSSIM model is provided. Second, the FSSIM-Dev household module used to represent both supply and household decisions is set out. Third, the main FSSIM extensions in term of model calibration as well as up-scaling results are presented.

2.1 FSSIM general description

FSSIM is a bio-economic farm supply model developed within the SEAMLESS project, to assess the impact of agricultural and environmental policies on the performance of farms and on indicators of sustainability. It consists of a data module for agricultural management (FSSIM-AM) and a mathematical programming model (FSSIM-MP). FSSIM-AM aims to identify current and alternative activities and to quantify their input and output coefficients (both yields and environmental effects) using the biophysical field model APES (Agricultural Production and Externalities Simulator) and other data sources. Once these activities have been generated, FSSIM-MP chooses those that best fit the farmer's behaviour, given the set of resources, the technological and political constraints, and forecasts farmer responses to new technologies, as well as to policy and market changes (Louhichi et al, 2010a). The principal outputs generated from FSSIM for a specific policy are forecasts on land use, production, input use, farm income and environmental externalities (e.g. nitrogen surplus, nitrate leaching, pesticide use, etc.). These outputs can be used directly or translated into indicators to provide measures of the impact of policies (Figure 1).

Figure 1. *An overview of FSSIM as a combination of Agricultural Management module and Mathematical Programming module (Louhichi et al., 2010b).*



FSSIM was designed sufficiently generic and with a transparent syntaxes in order to be applied to many different farming systems across Europe and elsewhere. It has a modular setup to be re-usable, adaptable and easily extendable to achieve different modelling goals. It includes a set of modules, namely crops, perennial, premium, Positive Mathematical Programming (PMP), risk, trend and policy (all separate modules). These modules are solved simultaneously; they are linked indirectly by an integrative module named the "common module" involving the objective function and the common constraints. Thanks to its modularity, FSSIM-MP provides the ability to add and remove modules (and their corresponding constraints) following the needs of the simulation, to select one or several calibration approaches between different options (risk, standard PMP, Rhöm and Dabbert' s PMP approach, Kanellopoulos et al. PMP approach) and to control the flow of data between the database and software tools. FSSIM-MP can be run with simple or detailed survey data (i.e. according to the level of detail of the available data).

FSSIM can be applied to individual (i.e. real) or representative farm (i.e. typical or average farm) as well as to natural (territorial) or administrative region by considering the selected region as a large farm (i.e. if the heterogeneity among farms inside the region is insignificant) or by aggregating the results of individual or representative farms (i.e. if the inter-dependencies between farms are minors). It can be used for two purposes: (i) to allow detailed regional impact assessment of policy decisions, market change and technological innovations on farming practices and sustainability of the different farming systems; (ii) to facilitate the link of micro and macro levels in integrated way through the estimation of supply-response functions that can be integrated in a partial equilibrium market model.

The mathematical programming module of FSSIM (FSSIM-MP) is a constraint optimization model which maximizes an objective function at given prices and subsidies subject to a set of resource and policy constraints. It consists of a non-linear programming model, which maximizes the farm's utility defined as the expected income minus risk, according to the Mean-Standard deviation method (Hazell and Norton, 1986). FSSIM-MP is referred to as a positive mathematical programming (Howitt, 1995a) model which integrates a large number of crop and animal activities.

The main specifications of FSSIM-MP are (Louhichi et al., 2010a):

(i) **A static programming model** which optimizes an objective function for one period (i.e. one year) over which decisions are taken. This implies that it does not explicitly take account of time. Nevertheless, to incorporate some temporal effects, agricultural activities are based on "crop rotations [1]" and "dressed animal[2]" rather than individual crops and animals.

(ii) **A positive model** in the sense that its empirical applications exploit the observed behaviour of economic agents to reproduce the observed production situation as precisely as possible;

(iii) **An activity based model** what means that one product can be produced by different activities, and each activity can produce several products. This makes suitable the integrated assessment of new policies which are linked to activity and not to product. This is the case or soil conservation policies in the USA, where all farm subsidies depend on the use of specific agricultural practices. In Europe, the Nitrate Directive is also an example of a policy targeting production processes, not products. This approach makes possible to take into account positive and negative jointness in outputs (i.e., joint production)

[1] Crop rotation is the practice of growing a series of dissimilar types of crops in the same area in sequential seasons for various benefits such as to avoid the build-up of pathogens and pests that often occurs when one species is continuously cropped.

[2] The concept of 'dressed animal' represents an adult animal and young stock taking into account the replacement rate.

(iv) **A primal based model** where technology is explicitly represented in order to simulate the switch between production techniques as well as between production systems;

(v) **A discrete based model** to integrate easily the engineering production functions generated from biophysical models and to account positive and negative jointness in outputs (i.e., joint production) associated with the production process. These specifications enable FSSIM to explore the impacts of policy changes and technological innovation not only on the relationship between market and nonmarket goods, but also on the production process.

(vi) **A template based model:** FSSIM-MP uses a model template for all the applications, i.e. the equations and variables used in FSSIM are the same everywhere but the set of parameters depend on farm data

The general mathematical formulation of FSSIM is presented below:

$$
\begin{aligned}
&\underset{x\geq 0}{Max}\ U = Z\text{-}\phi\sigma \\
&s.t \\
&Ax \leq B
\end{aligned}
\qquad (1)
$$

Where **U** is the farm utility function to maximise, **z** is the expected farm income, **x** is the nx1 vector of the simulated levels of the agricultural activities, **ϕ** is the risk aversion coefficient, **σ** is the standard deviation of income due to price and yield variation, **A** is a n×m matrix of technical coefficients, and **B** is a n×1 vector of available resources and upper bounds to the policy constraints.

The expected farm income is defined as total revenues including sales from agricultural products and compensation payments (subsidies) minus total variable costs from crop and animal production. Total variable costs include accounted linear costs for fertilizers, irrigation water, crop protection, seeds and plant material, animal feed and cost of hired labour as well as unaccounted cost due to management and machinery capacity reflected by the quadratic term of the cost function. Using mathematical notation, the non-linear income function can be presented as follow:

$$Z = p'q + p^{a}{}'q^{a} + (s'-c')x - d\,0.5x' \qquad (2)$$

Where **Z** is the expected farm income, **p** is the (n×1) vector of the expected product prices, **q** is the (n×1) vector of simulated sold products, $\mathbf{p^a}$ is the (n×1) vector of additional price that the farmer gets when selling within quota, $\mathbf{q^a}$ is the (n×1) vector of simulated sold products within quota, **x** is the (n×1) vector of the simulated levels of the agricultural activities, **s** is the (n×1) vector of subsidies, **c** is the (n×1) vector of accounting cost, **d** is the (n×1) vector of the linear part of the activities' implicit cost function and **Q** is the (n×n) matrix of the quadratic part of the activities' implicit cost function.

The accounting costs include costs for fertilizers, crop protection and seeds as well as plant material and cost of hired labor. **Q** and **d** are estimated using a variant of the Positive Mathematical Programming approach which guarantees exact reproduction of activity levels observed in the base year. In principle, any non-linear convex cost function with the required properties can reproduce the base year solution. For simplicity and lacking strong arguments for other type of functions, a quadratic cost function is usually employed.

The standard deviation of income **(σ)** is calculated according to the following formulation:

$$\sigma = \left(\frac{\sum_k (Z_k - Z)^2}{N} \right)^{1/2} \quad (3)$$

- **Z:** expected farm income
- **Z_k:** income over states of nature (k). Z_k is calculated using the same equation applied for calculating the expected income Z (i.e. equation (4)). The unique difference is that the average producer price (p) and the average yield (y) are replaced, respectively, by the producer price (p_k) and the yield (y_k) over state of nature (k). p_k and y_k are vectors of independent random numbers normally distributed (i.e. they are calculated using a normal distribution function based on the average and the standard deviation of price and yield). Due to data missing, we assumed that there is no dependence between yield and price variation (i.e. no covariance). This assumption could be improved if more data are available.
- **N** is the number of states of nature

Despite its strong relevance in both conceptual and technical terms (e.g., generic and modular setup, a suitable calibration approach, explicit representation of technology), the FSSIM model presents some limitations for representing farm-household behaviour in developing countries or/and rural areas. The first one is that as it is based on farm production theory, an approach which recognizes that production, labour allocation and consumption decisions are separable, so it is not suitable for rural areas where these decisions are interdependent. The second one is that land market, possibilities for off-farm labour, and structural changes are exogenously defined. The model independently simulates the behaviour of each farm, so it does not capture endogenously the interaction among farms which are very important in rural areas. The third limitation is its incapability to simulate the transition towards new production activities (i.e. new crop, rotations or production techniques) since model calibration is based on PMP approach with single observation. This approach is, in fact, unable to represent farmer behaviour with respect to production activities that are not observed during the reference period. This is termed self-selection problem that characterises most PMP approaches when single observation is used.
To overcome these problems, a significant number of improvement and extension was included in FSSIM-Dev such as the development of household module, the implementation of up-scaling component and the use of sound calibration methods. Moreover, taking into account the ambition of a generic tool, all the modifications are integrated in a manner that respects existing model architecture. This means that the resulting model is not a specialized African model, applicable to only African conditions but, rather, a model which can be applied to any relevant farming-householding systems in both developed and developing countries.

2.2 FSSIM-Dev household module

A literature review shows the existence of three alternative economic theories to model farm-household behavior. Each approach assumes that households have an objective function to maximize, with a set of constraints. First, the "profit-maximizing theory", which has been criticized on the ground that it overlooks the aspect of consumption in household decision processes. Second, the "utility-maximizing theory" which incorporates both the production and consumption goals of households. Finally, the "risk aversion theory", which states that the objective function of households is to secure the survival of the household to avoid risk (Mendola, 2007).
Utility-maximizing theory is the most requested when household consumption and production decisions are interdependent such as in rural areas. According to this theory, farm households are assumed to maximize the utility derived from consumption of all available commodities (i.e., home-produced goods, market-purchased goods, and leisure), subject to full income

constraints. Formally, the basic farm household model can be presented as follows (De Janvry and Sadoulet, 1995):

$$
\begin{aligned}
& Max\,U(c, c^{l}; z^{h}) \\
& s.t \\
& p^{a}c^{a} + w^{l}c^{l} = \pi + w^{l}E^{l} \qquad (4)\\
& f(q, x, l) = 0 \\
& B^{l} = c^{l} + l^{s}
\end{aligned}
$$

with

$$\pi = p^{v}v - p^{x}x - w^{l}l \qquad (5)$$

where **U** is a consumer's utility function defined over a vector of commodities consumed **c** and leisure $\mathbf{c^l}$, depending on household **h**'s characteristics $\mathbf{z^h}$. **f(q,x,l)** represents the household's production technology, relating farm outputs **q** to the amount of inputs **x** and labour **l**. $\mathbf{l^s}$ and $\mathbf{B^l}$ are the household's labour supply and the initial endowment of labour. $\boldsymbol{\pi}$ is the profit function, with $\mathbf{p^v}$, $\mathbf{p^a}$ and $\mathbf{p^x}$ are the vectors of selling prices, buying prices and input prices, respectively. **v** are the output quantities sold on the market and $\mathbf{w^l}$ the wage rate.

The basic model does not account for risk; therefore, if perfect markets are assumed, the household model is separable. The optimisation program can be solved recursively: first, the producer's profit maximization problem, then, the consumer's utility maximization problem, under the constraint of a given optimized level of profit. However, if market fails for a household, separability does not hold any more and the household's decision problem of production and consumption must be solved simultaneously.

Following Kuiper (2004), two approaches can be used to translate this theoretical framework to a quantitative household model: reduced-form equation and a system of structural equations. These approaches require selecting functional forms for the demand and supply functions. They may be derived from utility and production functions, or may be postulated (Kuiper, 2004). However, estimating household model in reduced-form or as a system of equations can be complicated. First, the structure of the household model may be too complex to derive a limited number of equations. Second, econometric estimation may be hindered by unobservable variables. If households produce commodities for home use only and do not offer its production on market sales, or use labour in production but does not participate in labour markets, these unobservable data limitations may prevent estimation. Third, econometric estimation set requirements in terms of number of observations, time-horizon and variation in variables (Kuiper, 2004).

A third approach relies on Mathematical Programming has been proposed in the last years (Omamo, 1998; Kruseman, 2000). This optimisation approach follows the general framework of an objective function maximised under constraints and solved the program though optimisation algorithms. Resting on numerical techniques, this approach does not require deriving first order conditions. However, a functional form to the objective utility function needs to be specified when *direct* utility function is used. The most common direct utility functions found in the literature are: *Negative Exponential utility function, Logarithmic utility function and Power utility function* (Kruseman, 2000).

Many efforts have been made to model functional forms which satisfy theoretical conditions. Large sections of Demand Theory have been dedicated to deriving demand functions directly from maximizing a utility function. However, this approach results in a reduction of the number of parameters to be estimated in the system of demand functions. Two of the latest demand systems, the Indirect Translog Model and Almost Ideal Demand System (AIDS), are called “flexible functional forms” as they do not require particular functional forms of utility functions. They come, respectively, from specifications of an *indirect* utility function and an expenditure function, which are both second-order approximation to any arbitrary indirect utility or expenditure function (Araar, 2002). In particular, the AIDS of Deaton and Muellbauer (1980) has become a widespread tool for analysing consumer behaviour. The PIGLOG (Price Independent Generalized Log-Linearity) indirect utility function, base for the AIDS demand system, is defined as follow:

$$V(R,p)=\frac{\ln R-\ln a(p)}{\ln b(p)} \qquad (6)$$

where **V(.)** is the farm household's indirect utility function, **R** is the farm household income, **p** are the prices of each good within the household's basket, **ln *a*(p)** and **ln b(p)** are the two price aggregates (See Appendix A)**.** If prices are given (defined exogenously), the two price aggregates **ln a(p)** and **ln b(p)** become constant terms. The natural logarithmic function being a monotonically increasing function, the optimisation program of the indirect utility function **V** is equivalent to maximising the income **R**. In case of market failures, some prices become endogenous to the model and both price aggregates are then function of the endogenous shadow prices specific to the household.
Building on the MP approach, contrary to Kruseman (2000), we suggest to use the indirect utility function, rather than the direct utility function, to model farm-household behaviours. However, we defend that maximising indirect utility function subject to technical production constraints enables to endogenise income and, thus, relax the separability assumption. To price all goods within the basket, in particular those for which markets fail, we introduce a full income and differentiate between three types of goods. According to this specification, the objective is to maximize the indirect utility function under technical production constraint:

$$\begin{aligned} &Max\, V=V(p^a,w^l,R)\\ &s.t.\\ &f(q,x,l)=0\\ &B^l=c^l+l^s \end{aligned} \qquad (7)$$

A set of additional constraints, including quantity balances on good *i* as well as consumption function, have to be added to this system:

$$\begin{aligned} &E_i+q_i+b_i=c_i+v_i\\ &c_i=c_i^0+dc_i=c_i^0+e_i\frac{c_i^0}{R^0}(R-R^0)+\sum_{j=1}^{n}e_{ij}\frac{c_i^0}{P_j^0}(p_j^a-p_j^{a0}) \end{aligned} \qquad (8)$$

Where the ***exogenous variables*** are:

- E_i, initial stock of good *i*;
- B^l, initial endowment of labour;
- p_i^v, selling price of good *i;*
- p_i^a, buying price of good *i*;
- p_i^x, price of input *i*;
- p_i^s, *shadow prices* of good i;
- e_i, income elasticity;
- e_{ij}, own and cross price elasticities of demand
- c^0, initial observed consumed quantity of good *i*;
- p^0, initial observed (buying or selling) price of good *i*;
- R^0, initial observed household income;

And the ***endogenous variables*** are:

- q_i , quantity produced of good *i*;
- c_i , quantity consumed of good *i*;
- v_i , quantity sold of good *i*;
- b_i , quantity bought of good *i*;
- c^l, leisure consumption;
- x_i , quantity of input *i* used in the production process;
- *l*, quantity of labour used in the production process;
- l^s, household's labour supply ($l^s = l^{on} + l^{off}$)
- l^{on}, household quantity of labour used *on the farm*;
- l^{off}, household quantity of labour *used off the farm*;
- l^{out}, quantity of labour recruited on the market;

In case of transaction costs, a distinction should be made between three types of goods according to the household being:

- A net buyer, i.e. his shadow price[3] is above the buying price p_i^a . Then, *i* is a tradable good: $i \in TNB$
- A net seller, i.e. his shadow price is below the selling price p_i^v . Then, *i* is a tradable good: $i \in TNS$
- Autarkic, i.e. his shadow price is between p_i^v and p_i^a . Then *i* is a non tradable good. The shadow price is equal, either to the marginal utility (more precisely to the ratio of the marginal utility of good *i* to the marginal utility of income for a monetary value), or the marginal cost of good *i*. $i \in NT$

About exogenous prices, it should be noted that the following relationships hold and allow solving the model:

$$p_i^v = p_i^a = \overline{p}_i^a \qquad \forall i \in TNB$$

$$p_i^v = p_i^a = \frac{\frac{\partial U}{\partial c_i}}{\frac{\partial U}{\partial R}} = \frac{\partial couttotal}{\partial q_i} = p_i^s = cm(q) = g(q) \qquad \forall i \in NT$$

$$p_i^v = p_i^a = \overline{p}_i^v \qquad \forall i \in TNS$$

$$v_i = 0 \qquad \forall i \in NT$$

$$b_i = 0 \qquad \forall i \in NT$$

$$v_i = 0 \qquad \forall i \in TNB$$

$$b_i = 0 \qquad \forall i \in TNS$$

The farm household's income **R** is defined as follows:

$$R = Z + w^l l^{off} + \sum_{i \in TNB} p_i^a (c_i - b_i) + \sum_{i \in TNS} p_i^v c_i + \sum_{i \in NT} p_i^s c_i \qquad (9)$$

where **Z** is the expected agricultural income, $\mathbf{w^l}$ is the wage, $\mathbf{l^{off}}$ is the quantity of labour used outside the farm, p_i^v is the selling price of good i, p_i^a is the buying price of good i, p_i^s is the

[3] The shadow price represents the value at which internal demand meet supply for household-produced goods (De Janvry, Fafchamps and Sadoulet, 1991).

shadow prices of good i, $\mathbf{c_i}$ is the consumed quantity of good i and $\mathbf{b_i}$ is the quantity bought of good i.

The farm household's income **R** is, thus, composed of expected agricultural income **Z**, the external income from offering labour (households may offer other market factors such as land and capital) $\mathbf{w^l l^{off}}$ and a fictive income. This last source of income is needed to take into account the fact that part of the production is dedicated to household's consumption. An interesting aspect is the price at which should be valued the auto-consumption. We argue that this price depends on the household being a net-buyer or a net-seller. Indeed, the opportunity cost of producing goods for home consumption for a net-seller is the forgone alternative of selling the commodity, i.e. the selling price. On the other hand, the trade-off for a net-buyer is between producing or buying the good on the market. The opportunity cost of producing goods for home consumption for a net-buyer is thus the forgone alternative of buying the commodity on the market (and dedicating time elsewhere[4]), i.e. the buying price. As a consequence, goods for which the household is a net-seller should be sold at the selling price and goods for which the household is a net-buyer at the buying price.

In this study, we are particularly interested to use this PIGLOG indirect utility function to model farm-household behaviours, assuming that **ln a(p)** and **ln b(p)** are fixed terms (i.e., the indirect utility function **V** is collapsed to maximising the household income **R**). Moreover, in order to take into account risk which is missing in the basic farm household model, we presume that household decision makers are expected utility maximizers and not income maximizers. According to this specification, the general mathematical formulation of the FSSIM-Dev, at farm household level, can be presented as follows:

$$\begin{aligned}
&Max\, \mathrm{V} = R - \phi\sigma \\
&s.t \\
&Ax \leq B \\
&E_i + q_i + b_i = c_i + v_i \\
&c_i = c_i^0 + dc_i = c_i^0 + e_i \frac{c_i^0}{R^0}(R - R^0) + \sum_{j=1}^{n} e_{ij} \frac{c_i^0}{P_j^0}(P_j - P_j^0) \\
&B^l = c^l + l^s
\end{aligned} \qquad (10)$$

where **V** is the farm household utility function to maximise, **R** is the farm household income, $\boldsymbol{\phi}$ is the risk aversion coefficient, $\boldsymbol{\sigma}$ is the standard deviation of household income due to price and yield variation, **A** is the matrix of technical coefficients, **B** is the initial available resources and upper bounds to the policy constraints, $\mathbf{c^l}$ is leisure consumption, $\mathbf{l^s}$ is the household's labour supply, $\mathbf{B^l}$ is the initial endowment of labour and $\mathbf{c_i}$ is the consumed quantity of good i as explained above.

Apart its consistency with theoretical literature and its easy implementation within the original FSSIM framework, this household formulation requires little information on households' consumption behaviours. Elasticities of demand suffice to parameterize the model. Furthermore, thanks to its flexible forms, this formulation doesn't rely on restrictive specifications of household's preferences. It account as well for the existence of a price-band which offers guidance for analysing the effects of transaction costs on household's production and consumption responses.

2.3 Other FSSIM improvements and extensions

Apart from the household module, FSSIM-Dev includes a set of technical specification which makes it suitable for representing relevant farming-household systems across Africa but also elsewhere.

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[4] One could think of subtracting a time proportional wage rate to the buying price.

The first one is the inclusion of new dimensions on data and variable structure which allow the simultaneous solve of farm-household models reproducing the behaviour of different farm households. Thanks to these new dimensions, it will be possible to simulate the interactions between farms such as the exchange on factor markets (land, labour and capital), the transfer of production and premium rights and the allocation of common resources, which are very important in developing countries. It permits as well the aggregation of results from farm household to village, regional or national levels. With this new specification, the FSSIM-Dev objective function becomes the maximization of village, regional or national utility/surplus at given prices and subsidies, based on the summation of the weighted expected utility of each representative farm household.

$$Max\,U = \sum_{h} we_h \left[R_h - \phi_h \sigma_h \right] \qquad (11)$$

where **h** denotes the farm household and $\mathbf{we_f}$ is the weight of each representative farm household **h** within the village/region.

For modelling the exchange of production factors (land, labour and equipment), a new variable was included in the right Right-Hand Side (RHS) of resource constraints representing tradable production factors among farm households. That is to say that for each production factor (ω), the available quantity in each farm household (h) will be equal to initial available quantity (B) plus quantity rented or leased from others (B^{out}) minus quantity rented-out (B^{off}) [5].

$$A_{h,\omega} x_{h,\omega} \leq B_{h,\omega} + B^{out}_{h,\omega} - B^{off}_{h,\omega} \qquad (12)$$

The second specification is the modelling of seasonality of demand and supply for production factors. In FSSIM, the decision period is the year which means that the seasonality of production activities as well as of demand and supply for production factors are not explicitly considered. That is, labour and equipment (i.e., traction) are constraining only at annual level, which means that they cannot be handled if they are limiting factors in certain seasons of the year. To take this into account, we have adopted a generic formulation in which the demand and the supply of production factors can be defined by year or by season within the year according to data availability and region condition.

The last specification is based on the enhancement of the calibration process by using a generic procedure to switch between three PMP approaches (Howitt (Howitt, 1995a), Rhöm and Dabbert (Röhm and Dabbert, 2003), and Kanellopoulos et al (Kanellopoulos et al, 2010) approaches) as well as between different PMP variants based on different weights of the linear and the non-linear cost functions (standard, average cost and almost-linear). It consists as well on the implementation of two new PMP approaches, namely Maximum Entropy-PMP approach (Heckelei and Britz, 2000) and Ordinary Least Square-PMP approach (Arfini and Donatti, 2008). These approaches are very useful when multiple data points are available as they reduce the arbitrator behaviour of the model, recover all the parameters of the cost function and capture the cross effects among production activities (Heckelei and Wolf, 2003).

As FSSIM, the core structure of FSSIM-Dev was designed generic and modular: 1.) to be re-usable, adaptable and easily extendable to achieve different modelling goals; 2.) to help define the production activities by crop or by rotation; 3.) to explicitly represent technology; and 4.) to smooth the integration of engineering data or results from bio-physical models needed to assess the environmental effects of production.

[5] Similar equations are used to capture the transfer of production (i.e., quota) and premium rights among farm households. (For labour; $B_{h,\text{“labour”}} = B^l$)

In addition to the set of outputs generated by FSSIM, the FSSIM-dev allows to assess the impact of production and consumption decisions on variables of interest, including farm household welfare, market exchange, household resource use and sustainability issues.

3. Results from a Survey in Sierra Leone

In the case of developing countries, particularly in Africa, the adequate collection of farm household data is crucial to inform modelling exercise such as FSSIM-Dev which may help not only to evaluate aid efficiency but to analyze in detail the key determinants to improve smallholders 'livelihoods. Therefore, there is urgency in securing better statistics for rural areas which better reflect the nature of economic activities farm households.

In this respect, the survey designed for the assessment of STABEX-funded projects in Sierra Leone can shed some light on potential improvements both in terms of data measurement techniques of key variables and in assessing the interconnections of farm households with their immediate chiefdom or village context by incorporating theories of farm household behaviour as examined in the FSSIM-Dev household module section addressed above. For this purpose, section 3.1 introduces the survey and main characteristics of smallholders in Sierra Leone. Section 3.2 describes two income measurement methods based on farm households degree of market integration and objectives of profit vs. utility maximization.

3.1 Smallholders in Sierra Leone

The government of Sierra Leone requested in 2005 the use of European Union STABEX (Stabilization of Export Earnings) funds (an instrument of the 8^{th} EDF – European Development Fund) for the enhancement of national rice production and the rehabilitation of cocoa and coffee plantations to achieve food security goals and improve the agricultural export sector of the country. Most of the support provided (4,378,000 EUR) focused on smallholders' needs and performance. Technical assistance initiatives were aimed at improving (i) smallholder agricultural productivity, (ii) current and potential farm income and, more generally supporting poverty alleviation in vulnerable rural areas. The survey at hand was therefore originally aimed at capturing the effect of this aid programmes on smallholders in Sierra Leone. The Sierra Leone survey consists of 604 smallholders (distributed among 5 districts of the Northern and Eastern regions of the country) and was carried out in 2009 as the implementation of STABEX-funded projects was concluding. Quantitative and qualitative data was collected from smallholders through two questionnaires and face to face interviews that were realised during multiple visits. More than 90 per cent of the surveyed smallholders were recipients of STABEX-funded aid programmes.

Survey results confirm that smallholders (on plots averaging not more than 2 acres per worker) not only constitute the big majority of farmers in Sierra Leone but are characterised by highly inefficient input/output mixes on top of high pre harvest and post harvest losses. Farmers lack access to yield-increasing inputs (such as improved tools or fertilizers) and face limited ability to invest in economic activities not only due to credit shortage but also to institutional arrangements which do not support using land as collateral for loans[6]. Lastly, reduced cash-income keeps smallholders particularly exposed to remain in the poverty-trap. Table 1 below introduces the main differences between surveyed smallholders from the Northern and Eastern districts.

Table 1 *Basic Comparison of smallholders in the surveyed Northern and Eastern Districts*

Northern Districts: Tonkolili and Bombali	**Eastern Districts: Kenema, Kono and Kailahun**

[6] In Sierra Leone, land is perceived as communal asset which belongs not only to the living relatives but to those who have passed away or have not yet been born.

Factors of production:	
- Smaller plots and less land availability per household unit	- Larger plots and more land availability per household unit
- Crop orientation: mainly rice and no cash tree crop	- Crop orientation: cash tree crop (coffee, cocoa)
Production (rice):	
- Lower yields	- Higher yields
- Higher losses	- Lower losses
Limited cash income	**More cash income**
- Higher diversification of household income (particularly off farm)	- Lower diversification of household income

In the Northern districts where the agro-ecological setting does not allow for cash tree crop cultivation, smallholders produce staple crops (mainly rice) which fulfil domestic consumption needs. In the Eastern districts, smallholders are further integrated to the market as crops such as coffee and cocoa usually for export purposes. Figure 3 and 4 summarize the allocation of acreage to different crops in the two regions.

Figure 3 *Allocation of acreage to different crops for the median farm in the Eastern region of Sierra Leone.*

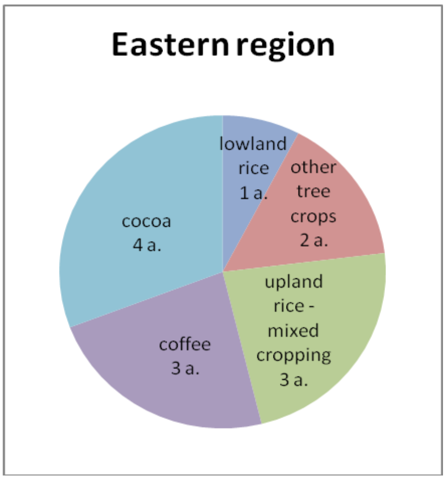
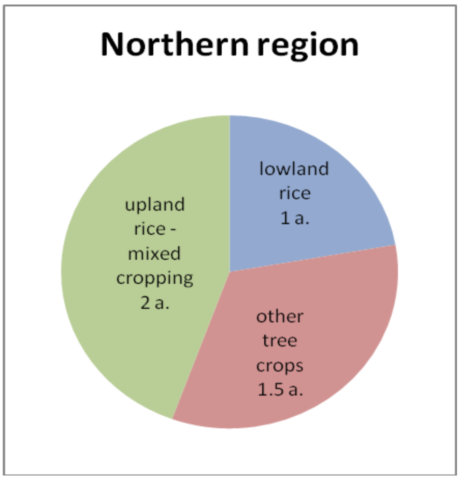


Figure 4: *Allocation of acreage to different crops for the median farm in the Northern region of Sierra Leone.*



In this context, survey results indicate that smallholders in the Northern region are more likely to depend on additional non-agricultural income sources in order to support the farm households while in the East smallholders are more dependent and focused on agricultural activities. For instance, in the Eastern region, 5.7 members of households, on average, take part in farming activities, 15% of which are part-time. In the Northern region, 5.1 household members are involved in farming, 25% of which are part-time.

Table 2 *Smallholder Resources*

	Northern region			Eastern Region	
	Bombali	Tonkolili	Kono	Kenema	Kailahun
1. Land (acres)	6	7,3	14,9	17,5	13,3
(acres/person)	-0,8	-0,9	-2,5	-1,8	-1,3
2. Labour (nos.)	8,5	9,3	7,7	11	13
(adult equivalent)	-7,5	-8	-6	-10	-10,4
men	2,3	2,4	1,9	3,5	3,5
women	2,4	2,5	1,9	3,4	3
children	4,8	5,4	3,9	5,6	6,7
Extended family (nos.) (adult equivalent)	12	13	10	21	19
	-9,7	-10,6	-8	-16,8	-15,9
3. Livestock (Leones)	191 028	284 372	217 222	238 688	208 530
(% households owning)	-0,62	-0,67	-0,75	-0,82	-0,61
sheep	2,5	2,3	1,5	2	3,6
	-0,13	-0,18	-0,17	-0,27	-0,07
goats	2,3	2,9	1,5	2,1	2,8
	-0,13	-0,21	-0,31	-0,28	-0,25
chickens	7	8,6	6,7	4,9	7
	-0,59	-0,61	-0,65	-0,78	-0,51
other poultry	3,3	5,1	10	0	0
	-0,04	-0,09	-0,26	0	0
4.Agricultural stocks (Leones)	380 891	275 830	640 184	951 121	2 248 502
(% households having stock)	-0,97	-0,95	-0,88	-0,94	-0,96
upland rice (bushels 1 bushel ~20kg)	4,9	4,4	13,3	12,5	4,7
	-0,6	-0,89	-0,82	-0,93	-0,79
IVS rice (bushels)	4,3	2,8	8,7	10,4	3,6
	-0,65	-0,47	-0,26	-0,63	-0,75
boli rice (bushels)	10,2	0	0	0	0
	-0,28	0	0	0	0

Table 3 *Educational composition of farming households in the Eastern and Northern regions of Sierra Leone.*

	Eastern region	Northern region
Education of head (average over heads with education)	8.3 yrs.	9.2 yrs.
(% without any education)	67%	72%
Education of spouse (average over spouses with education)	7.8 yrs.	7.0 yrs.
(% without any education)	86%	89%
% of children in school	62%	60%
% of children not in school	38%	40%

Table 2 and 3 further summarize the differences between farm households in the Eastern and the Northern regions in Sierra Leone. While in the Eastern region, smallholders not only enjoy larger access to land and labour inputs, household heads also appear to have reached higher educational level than those of the Northern districts.

3.2 Evaluating two income calculation methods

A comprehensive measure of farm-household income is a key indicator which considers all household activities. However, given the focus of the Sierra Leone survey, it is not possible to account for all non-farm income and thus agricultural production activities rather dominate farm household income calculation in this case. The general calculation process of the farm household income is given in Table 4.

Table *4 Income Calculation*

Economic Indicators	**Calculations**
Net Farm Income (NFI)	= Output Value – Input Costs
Gross Margin (GM)	= Output Value – Variable Costs
Net Cash Income (NCI)	= Value of Sales – Variable Costs in cash
Output Value (OV)	Sales, Consumption and Stocks
Input Costs (IC)	Variable Costs (i.e. household and hired labour, seeds and livestock purchase) and Fixed Costs (tools and land rent)

Net Farm Income (NFI) is determined on a micro scale using technical and economic parameters, i.e. yield, off-farm prices of the produce, production costs and depreciation, it does not include policy parameters, such as (subsidies, credits, taxation[7] and market policies). The latter in the context of the surveyed smallholders is obtained by subtracting all *Input Costs* from *Output Value* for each individual household. The *Gross Margin* (GM) is calculated as the difference between the *Output Value* and the *Variable Costs*. *Net Cash Income* (NCI) excludes non-monetary transactions in the access of farm inputs. *Output Value* (OV) represents all agricultural production: for sale, self-consumption and stocks. The output value for sale was calculated from the market prices declared in the survey of each household. It should be noted that stocks include the seeds which may be used as input in consequent production cycle. *Input*

[7] Smallholders in the survey are not subject to agricultural taxation. (Jalloh, 2006)

Costs (IC) of the production is the sum of *Variable Costs* and *Fixed Costs*. *Variable Costs* are proportional to the amount of the production (labour, seeds, livestock purchase). *Fixed Costs* include the value of fixed assets such as land, tools, machinery, buildings. Our survey results show hardly any machinery and building assets in the possession of smallholders, thus these components are not included in the calculation. Likewise, information on tree crops is not available in the survey. Therefore, it is not possible to estimate their sunk cost value.

There are however, specific challenges related to the data collection and measurement processes in West Africa; which are well reflected in the Sierra Leone experience (besides the difficulties in capturing all types of non-farm income sources). These challenges, as argued by Ellis (1993), are mainly due to the complex interrelationships between farm households' assets, access and activities. On one hand, it is difficult to impute value to self-consumption; on the other, there is the question of how to calculate opportunity cost in absence of functioning markets, particularly when it comes to household labour use and decisions. Equally, there are problems in the accounting in monetary terms for some inputs. In this respect, the analysis of the Sierra Leone case study reveals that it is common for farmers within villages to organize labour groups in order to look after the different plots. It also shows that smallholders maintain strong bonds at the village level which allow them to secure access to other inputs such as seeds (up to one fourth of their needs are said to be supplied under this type of mechanisms) (SLIHS, 2007). The exchange of the above mentioned inputs is based on the notion of reciprocity. As explained by Ellis (1993) *"reciprocity may involve social norms of sharing and redistribution which are designed to ensure that all members of the community survive irrespective of the year to year productive performance of individual households"*. Other authors have denominated this behaviour as *"the economy of affection"* (Hyden, 1980) or *"the moral economy"* (Scott, 1976).

In order to account for the existing socio-economic connections between farm households and their village or chiefdom in Sierra Leone, two income calculations based on the principles of profit maximization vs. utility maximization (in the context of complete vs. incomplete markets) were implemented in order to serve as basis of a comparative analysis. In the first one, market values are used to impute output value and costs of all inputs employed at the farm level (i.e. household and hired labour, seeds, livestock purchases and tools are quantified by taking into consideration observed market wages and prices as reported in the survey). In the second it is considered that farm household are not fully integrated to markets and are in fact highly dependent on their context. The latter allows them to reduce direct or indirect costs related to the access of inputs while simultaneously taking into consideration that the amount of output for self-consumption has a higher value for smallholders than the current market price. The key assumptions under each of these two approaches are summarized in Table 5.

Table 5 *Comparative summary of two income calculation methods: integrated markets and semi-integrated markets*

	Integrated Markets (IM)	**Semi-Integrated Markets (SIM)**
Objective	profit maximization	utility maximizing
Market Assumption	competitive markets	competitive product market & no labour market
Output Valuation		
sales consumption & stocks	market price market price	market price 10% higher than market price
Input Cost Valuation		
household Labour	wage (opportunity cost)	no cost (opportunity cost = 0)

hired Labour	wage	mo cost – food cropping wage – cash tree cropping
seeds livestock tools land rent	market price market price depreciation cost market price equivalent of bushels of rice paid	market price market price depreciation cost market price equivalent of bushels of rice paid

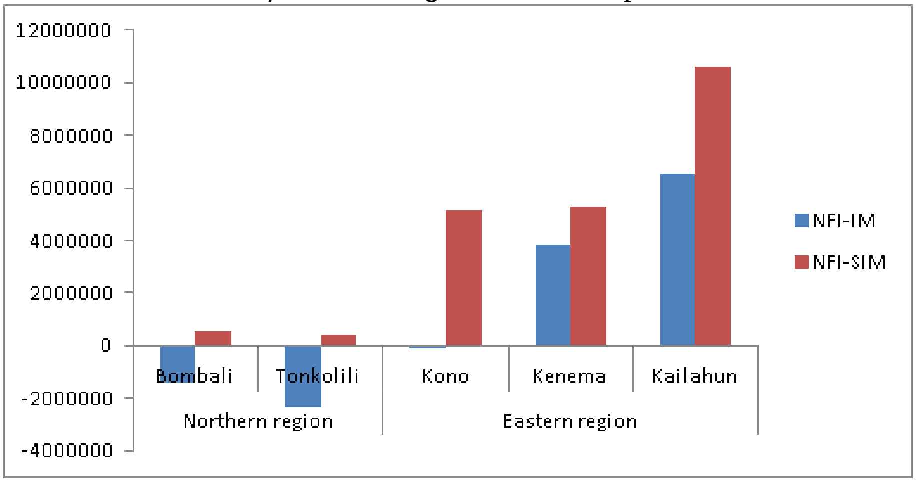
Under the income calculation guided by profit maximization (IM or Integrated Market income calculation), it is assumed that smallholders operate under competitive market conditions (i.e. output/input price takers, high number of suppliers, zero information and transaction, markets not influenced by producers/consumers, no entry or exit barriers, etc.). Under the Semi-Integrated Market (SIM) income calculation, it is assumed that the goal of farm household is utility maximization and risk minimization along with a simple reproduction rather than profit maximization (Ellis 1993).

Sales under both approaches are valued at market price (as observed in the survey). While under the Neoclassical approach, *consumption and stocks* are also valued at the market price. Yet under the SIM income calculation process, these two components of the output are assumed to be valued at a 10% higher than the market prices. This ten percent was based on the assumption of purchasing at retail price rather then market (selling) price) as alternative for self production, the price difference of the local and imported rice was taken as a base for the calculations. Several studies deal with the evaluation of the self subsistence production, where the output value of the staple food was generally valued near retail price, which is higher then the market price, up to 20-40% higher in some cases (Chibnik 1978). This comes from the fact that farm households prefer to secure their food and avoid risks and uncertainties of future unpredictable market economy.

Under the income calculation guided by profit maximization theory, the marginal valuation of *labour* is equal to market wage. However this does not apply for the farmers operating in areas where labor market is limited/inexistent (Colman & Young 1989). According to Ellis (1993) it is more consistent and analytically useful to consider farm households in terms of their only partial integration into the market economy and the incomplete markets within which they operate. In the SIM income calculation, the highly constrained or non-existent labour market means that the household labour cannot be effectively valued at market opportunity wage, thus, it is assumed to be close to zero. This follows earlier approaches already applied for similar cases and circumstances (cf. Dasgupta, Marglin and Sen (1972) and Little and Mirrlees (1974)). When there is no labour market, until the value of output riches the minimum subsistence level, the marginal valuation of labour is equal to zero, and leisure cannot be valued at any price (Coman & Young 1989 p.156 top). On commercial farms (also defined as entrepreneurial farms, or capitalist farms), increases in labour input without concomitant income gains can lead to losses because profit equals output value minus outlay on materials minus wages, minus other payments (e.g. debt-interests, land rent, etc.). On family/peasant farms, however, increases in (family) labour inputs without corresponding increases in income do not necessarily lead to monetary losses because of the absence of wages. Similarly, hired labour can be assumed to be close to zero given that the labour sharing schemes take place without engaging in monetary transactions.

Figure 5 summarizes the results obtained under the two income calculation methods. It can be observed that the existing relationships between farm households in a village are ignored, the majority of smallholders in the Northern region can be deemed unviable to the point that simple reproduction of the farming system would be even ensured. On the other hand, smallholders in the Eastern districts appear as viable under both calculation methods. These results indicate how income and farm household behaviour analyses may become obscured if a proper understanding of the institutional setting is absent. (Table 6 below presents the results of the Net Farm Income calculation in more detail)

Figure 5 *Net Farm Income based on Integrated Market and Semi-Integrated Market income calculation methods for an average smallholder per district*



Under the income calculation which embraces utility maximizing theory (which relies on a partial integration to the market economy) smallholders are not only assumed to face incomplete market but the chiefdom/village institutional setting is integrated to the estimation procedure. Quantitative evidence for the *Net Farm Income* suggests that this approach is closer to the context in which farm households produce and interact. 86% of the farm households located in the Northern districts achieved a positive NFI, meaning that they are viable and only 14% obtained negative results. In the Eastern districts, 97% of the smallholders secured positive NFI and only 3% did not. The fact that under both income calculations, smallholders in the Eastern region come out as viable farm households reflects their closer interaction and integration to related tree crop output and labour markets. In the cases of cocoa and coffee, harvested output is not for self-consumption but rather for market sales. Likewise, hiring labour for peak collection or harvest periods requires additional support than that of village work sharing schemes. The latter implies that to a certain extent, farm households in the Eastern districts engaged in cash tree cropping are better equipped to act as a separate or self-standing unit of production and are therefore less dependent than farmers in the Northern districts on the village institutional arrangements to secure agricultural production.

Table 6 *Economic results of the smallholders per average farm by districts (in Leones/year)*

Economic variables	Northern region		Eastern region		
	Bombali	Tonkolili	Kono	Kenema	Kailahun
Integrated Market Method					
Net Farm Income	-1425998	-2323202	-100429	3842484	6554646
Farm Gross Margin	-1342740	-2220772	-67480	4093419	6659602
Output Value	1019770	867946	5396101	6250815	12634378
sales	314192	301437	4331568	4451269	7011220
consumption	269113	265362	497995	759551	2902599
stocks	436466	301147	566538	1039995	2720559
Input Costs	2445768	3191148	5496530	2408330	6079732
Variable Costs	2362510	3088717	5463581	2157396	5974776
seeds	251031	227167	153161	253174	1259378
livestock purchases	175064	159897	25673	154463	118861
hired labour	1009642	1381893	332310	926205	2107675
household labour	926773	1319759	4952437	823554	2488863
Fixed Costs	83258	102430	32950	250935	104956
tools	82952	101976	32950	250935	103956
land rent	306	454	0	0	1000
Semi-Integrated Market Method					
Net Farm Income	580974	435102	5151356	5311385	10605376
Farm Gross Margin	664233	537532	5184306	5562320	10710332
Output Value	1090328	924596	5502554	6430769	13196694
sales	314192	301437	4331568	4451269	7011220
consumption	296024	291898	547794	835506	3192859
stocks	480112	331261	623192	1143994	2992615
Input Costs	509354	489495	351198	1119384	2591318
Variable Costs	426095	387065	318249	868449	2486362
seeds	251031	2327	24054	0	1102893
livestock purchases	175064	159897	25673	154463	118861
hired labour	0	0	139415	460813	1108124
Fixed Costs	83258	102430	32950	250935	104956
tools	82952	101976	32950	250935	103956
land rent	306	454	0	0	1000
Farm Net Cash Income	71261	83003	4249564	4233513	5750345

4. Conclusions and Recommendations

This paper provides a detailed description of the bio-economic farm household model (FSSIM_dev), especially its specifications, structure and component integration. The original contributions of FSSIM-Dev to farm household modeling are (i) the use of indirect utility function, relying on mathematical programming, in order to model farm-household behaviors; (ii) the employ of sound calibration methods to reproduce farm production decision; (iii) the explicit modeling of production factor trade which are very significant in rural area and (iv) the implementation of aggregation component to up-scale results from farm to village, regional or national level. However, a key challenge is securing the level of detailed data required to feed into the model.

In this respect, survey results from Sierra Leone illustrate the limitations in securing accurate income calculation which usually rises from the fact that incomes are usually derived from spatially dispersed sources and involve self-employment activities in which personal income and business cash flow are inextricably woven together. (Ellis 2000). As a consequence, it is impossible to analyze whether diversification (beyond that of agricultural activity) is in fact an effective livelihood strategies for the surveyed smallholders (a feature which is accounted for in the construction of FSSIM-Dev household module). As stated by Ellis (2000) it is important to know the actual rather than the hypothesised activity portfolios of poor rural people, and how these are changing over time, so that support can be provided that facilitates and strengthens emerging, rather than declining patterns of activities - (timeliness). It is also useful to know in a particular location how poor people's livelihood strategies differ from those of the better off (ibid).

Another important institutional factor, not captured in the survey at hand, is that farm household decisions across the country are not entirely made at that level but mainly rely on the *paramount chief*. The latter is exemplified in the way land is managed. In Sierra Leone land market transactions (renting, selling or buying) are strongly reduced by costmary rules. The notion that the enlarged farm-household family (including the dead and the unborn) has to agree in land transactions represents a crucial bottleneck. Likewise, the short (1-2 years) time horizon of renting agreements, inhibits renters' investments in facilities (such as irrigation, drainage, processing constructions, etc.) and in permanent crops (trees), resulting, in the very end, in a crucial limiting factor for growth of land and labor productivity. Under this context, where land is not considered to belong to individuals but rather to the village and the extended families, land markets are largely underdeveloped. In other words, ideally the collection of data should be performed at the farm household and the village or chiefdom level in order to better capture the nature of these decisions and their impact on economic performance. To summarize, a major improvement in future surveys lies in distinguishing key players in the decision-making process regarding agricultural production as well as a deeper understanding of the institutional background. Also, it would be interesting to analyze whether the *paramount chief* has influence in other off farm economic activities, such as petty trade or small scale manufacturing. Ellis (1993) argues that field methods aimed at investigating rural poverty may be improved by combining sample surveys with participatory approaches such as the Participatory Rural Appraisal (PRA). While the principal strength of the sample survey is its capacity to yield detailed quantitative information at a household/individual level, PRA may be able to capture some of the complexity involving farm-household relations and their immediate socio-economic and institutional environment. Likewise, another way to overcome the problem of non-monetary transaction is to set up more detailed surveys which not only describe the nature of exchanges but that integrate information on caloric intakes of different household members. To conclude, by explicitly considering these issues in the elaboration of farm household surveys, it will be possible not only to feed more adequate data to the household module of FSSIM-Dev but to improve the analysis of income generation and production practices in the contexts of tropical agricultural systems in West Africa.

REFERENCES

Araar, A., 2002. L'impact des variations des prix sur les niveaux d'inégalité et de bien-être : une application à la Pologne durant la période de transition. *L'Actualité Economique*, 78(2): 221-242.

Arfini F., Donati M., 2008. Health Check and farm efficiency: a comparative assessment of four European agricultural regions. Paper presented for the 109th Seminar of the EAAE. The CAP after Fischler Reform: national implementations, impact assessment and the agenda for future reforms, November 20-21 2008, Viterbo.

Barbier, B., Bergeron, G., 1999. Impact of policy interventions on land management in Honduras: results of a bio-economic model. *Agricultural Systems*, 59, pp. 1-16.

Boadway, R. 2006 Principles of Cost-Benefit Analysis *Public Policy Review*, Vol.2, No.1 2006

Buysse, J., Fernagut, B., Harmignie, O., De Frahan, B.H., Lauwers, L., 2007. Farm-Based

Modelling of the EU Sugar Reform: Impact on Belgian Sugar Beet Suppliers. *European Review of Agricultural Economics*, Vol. 34, No. 1, pp. 21-52, 2007.
Chayanov, A.V. 1966 The Theory of Peasant Economy (translated from Russian and German editions published in 1920) Homewood, Illinois.
Chibnik, M. 1978 Value of Subsistence Production, *Journal of Anthropological Research*, Vol 34, No. 4, p 561-576 1978.
Colman, D. and Young, T. 1989 *Principles of Agricultural Economics. Markets and Prices in Less Developed Countries*. Cambridge University Press
Dasgupta, P., Stephen M. and Sen, A. 1972 *Guidelines for Project Evaluation* New York: UNIDO.
De **Janvry and Sadoulet,** 1995. Chapter 6 : Househols Models, in Quantitative Development Analysis, The Johns Hopkins University Press, pp.140-175.
De **Janvry, A., Fafchamps M., Sadoulet, E.,** 1991. Peasant household behaviour with missing markets: Some paradoxes explained. Economic Journal, 101, pp. 1400–1417.
Deaton, A., Muellbauer, J., 1980. An Almost Ideal Demand System. *American Economic Review*, vol. 70(3), pp. 312-26.
Ellis, F 1993 *Peasant Economics. Farm households and agrarian development*. Second edition. Book, p.309
FAO Food and Agriculture Organization (1999) *Guidelines for Agrarian Systems Diagnosis*
Heckelei, T., Britz, W., 2000. Positive mathematical programming with multiple data points: a cross-sectional estimation procedure, *Cahiers d'Economie et Sociologie Rurales*, 57, pp. 28-50.
Heckelei T., Wolff, H., 2003. Estimation of Constrained Optimisation Models for Agricultural Supply Analysis Based on Generalised Maximum Entropy. *European Review of Agricultural Economics*, 30(1), pp. 27-50.
Holden, S. T., Shiferaw, B., Pender., J., 2004. Non-farm income, household welfare and sustainable land management in a less-favoured area in the Ethiopian highlands. *Food Policy*, 29, pp. 369–392.
Howitt, E.R., 1995a. A calibration method for agricultural economic production models. *Journal of Agricultural Economics*, 46, pp. 147-159.
Hyden, G. 1980 *Beyond Ujamaa in Tanzania: Underdevelement and an Uncaptured Peasantry*. London: Heinemann
Jalloh 2006 *Country Study: Sierra Leone. re for Agricultural and Rural cooperation* CTA July 2006. Project 4-7-41-2007/5b
Kanellopoulos, A., Berentsen, P.B.M., Heckelei, T., Van Ittersum, M.K., Oude Lansink, A.G.J.M., 2010. Assessing the forecasting performance of a generic bio-economic farm model calibrated with two different PMP variants. *Journal of Agricultural Economics*, 61(2), pp. 274-294.
Kruseman, G., 2000. Bio-economic Household Modelling for Agricultural Intensification. PhD dissertation, Wageningen University, Wageningen. 283p.
Kuiper, M.H., 2004. Village modelling – A Chinese recipe for blending general equilibrium and household modeling. PhD thesis Wageningen University, Wageningen, 261p.
Little, I. and Mirrlees J. 1974 *Project Appraisal and Planning for Developing Countries* New York.
Louhichi K., Janssen, S., Kanellopoulos, A., Li H., Borkowski, N., Flichman, G., Hengsdijk, H., Zander, P., Blanco, M., Stokstad, G., Athanasiadis, I., Rizzoli, A.E., Huber, D., Heckelei, T., Van Ittersum, M., 2010a. A generic Farming System Simulator. Environmental and Agricultural Modelling: Integrated Approaches for Policy Impact Assessmen, Brouwer, F., van Ittersum, M.K. (Eds.). Springer Academic Publishing, 2010. ISBN: 978-90-481-3618-6.
Louhichi K., Kanellopoulos A., Janssen S., Flichman G., Blanco M., Hengsdijk H, Heckelei T., Berentsen P., Oude Lansink P., Van Ittersum M., 2010b. FSSIM, a Bio-Economic Farm

Model for Simulating the Response of EU Farming Systems to Agricultural and Environmental Policies. *Agricultural Systems*, (2010), vol. 103, n° 8, pp. 585-597.
Mendola M., 2007. Farm Household Production Theories: A Review of Institutional and Behavioral Responses. *Asian Development Review*, vol. 24, no. 1, pp. 49-68.
Okumu, B. N., Jabbar, M. A., Colman, D., Russell., N., 1999. Bio-economic modelling of watershed resources in Ethiopia Paper presented to the annual meeting of the American Agricultural Economics Association, Aug/99. (Vatn et al., 1997; Falconer and Hodge, 2001; **Wossink, G.A.A., Oude Lansink, A.G.J.M., Struik, P.C.,** 2001. Non-separability and heterogeneity in integrated agronomic-economic analysis of nonpoint-source pollution. *Ecological Economics*, 38, 345-357.
Omamo, S.W., 1998. Transport costs and smallholder cropping choices. *American Journal of Agricultural Economics* 80 (1), pp.116-123.
Röhm O, Dabbert S., 2003. Integrating agri-environmental programs into regional production models: an extension of positive mathematical programming. *American Journal of Agricultural Economics*. 2003, 85, pp. 254–265. doi: 10.1111/1467-8276.00117.
Scott, J.C. 1976 *The Moral Economy of the Peasant*. New Haven. Yale University Press
Sesay J. 2008 *Synopsis, challenges, potential and vision for agriculture in Sierra Leone with emphasis on rice production, Minister of Agriculture, Forestry & Food Security of Sierra Leone* http://www.maffs.gov.sl/DocumentsandReports/Sectorrelated/tabid/114/Default.aspx Accessed on the 11/12/09
Shepherd, K. D., Soule, M. J., 1998. Soil fertility management in west Kenya: dynamic simulation of productivity, profitability and sustainability at different resource endowment levels. *Agriculture, Ecosystems and Environment*, 71, pp.131-145.
Singh, I., Squire L., Strauss, J., 1986. Agricultural Household Models: Extensions, Applications and Policy. Johns Hopins Umverslty Press, Baltimore, Maryland, 323p.
SLIHS (2007) *Sierra Leone integrated household survey (SLIHS) 2003/04* Department for International Development, GoSL Government of Sierra Leone http://www.statistics.sl/SLIHS_REPORT.pdf
Taylor, J.E., Adelman, I., 2003. Agricultural household models: Genesis, evolution and extensions. *Review of Economics of the Household*, 1(1), pp.33-58.
Van Ittersum, M.K., Ewert, F., Heckelei, T., Wery, J., Alkan Olsson, J., Andersen, E., Bezlepkina, I., Brouwer, F., Donatelli, M., Flichman, G., Olsson, L., Rizzoli, A.E., van der Wal, T., Wien, J.E., Wolf, J., 2008. Integrated assessment of agricultural systems – a component-based framework for the European Union (SEAMLESS). *Agricultural Systems*,96, 150–165.

Appendix

A – PIGLOG Utility function

The PIGLOG (Price Independent Generalized Log-Linearity) indirect utility function, base for the AIDS demand system, is defined as follow:

$$V(R,p)=\frac{\ln R-\ln a(p)}{\ln b(p)} \tag{13}$$

where **V(.)** is the farm household's indirect utility function, **R** is the farm household income, **p** are the prices of each good within the household's basket, **ln *a*(p)** and **ln b(p)** are the two price aggregates**.**

$$\ln a(p) = \alpha_0 + \sum_{i=1}^{n} \alpha_i \ln p_i + \frac{1}{2} \sum_{i=1}^{n} \sum_{j=1}^{n} \gamma_{i_j} \ln p_i \ln p_j$$

(6)

$$\ln b(p) = \beta_0 \prod_{i=1}^{n} p_i^{\beta_i}$$