Economic and Distributional Impacts of Biofuels in Mali

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Abstract: For a few years, a biofuels race has been observed because of the increasingly high cost of oil and the increasing importance attached to environmental protection at the world level. Unfortunately, one notes at the same time a bond established between the rising prices of foodstuffs and the development of biofuel production. Also, the development of biofuels in Mali must satisfy the double objective of compensating the difficulties of oil product supply and avoiding overly compromising food safety because of excessive pressure on grounds that can be cultivated for ends other than cereal production.

This study carries out a thorough review of the prospects of large-scale expansion of biofuels in the country, and its economic and distributional impacts. We look for the investment, production, consumption and trade of biofuels and the corresponding feedstocks, potential roles for biofuels considering country-specific policies and priorities on food and energy supply. Special focus is given to different varieties of jatropha. Economic and distributional impact assessment of biofuel technologies in Mali is performed with a microsimulation CGE model. Specifically, we use the top-down sequential approach given the microdata challenges. The distributional analysis includes application of poverty (FGT), income distribution (GINI) and pro-poor growth analysis.

Keyword: Biofuels, agriculture, computable general equilibrium model, micro-simulation, distributional analysis.

JEL: D58, D31, I32, Q17

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1 Introduction

A number of developing countries have set targets for supplying energy from biofuels. For example, India plans to meet 20% of its total transportation fuel demand through biofuels by 2017 while Brazil is planning to expand its biofuel exports. However, the 2007-2008 food crisis has generated some concerns regarding the expansion of biofuels. Although there is no clear consensus on the cause of the food crisis, analysts suggest that the production of biofuels is one of the key reasons for the increase in global food prices (Mitchell, 2008; Headey and Fan, 2008; Baier, Clements, Griffiths and Ihrig, 2009). Moreover, the environmental friendliness of biofuels (for example, the degree of carbon neutrality, the impact on land use and carbon release, water depletion and pollution, biodiversity loss and air quality degradation) has also been questioned (Doornbosch and Steenblik, 2007; Searchinger et al. 2008; Fargione et al. 2008; OECD, 2008).

In spite of these charges, some Sub-Saharan African countries, such as Mali, have expressed interest in biofuels because these countries do not have significant land supply constraints for producing biofuels and they are dependent on imported fossil fuels for meeting their transportation fuel demand. The energy consumption of Mali, in 2002, was 3.2 million tons oil equivalent (Mtoe). This consumption is dominated by the biomass to a total value of 81% (wood, charcoal). Also, the country is strongly dependent on petroleum products imported primarily via the ports of Ivory Coast and Senegal. These petroleum products account for 16% of energy consumption. The average rates of annual increase in the hydrocarbon imports during the decade 1994-2003 were approximately +33% for super gasoline, +4% for regular gas and +13% for gas oil. According to estimates, the national demand for hydrocarbons will reach one million tons in 2010, nearly 2 million in 2015 and more than 3 million in 2020. As for electricity, its share is 3% in the national energy balance. In 2004 only 13% of the Malian population had access to electricity, with strong disparities between urban and rural areas. Moreover, this weak access is compounded by a weak share of renewable energies. However, Mali has strong potential in this field with solar energy, wind energy and bioenergy (pourghère,[5] cotton stems, etc). It is only in 2006 that Mali worked out its national strategy for developing biofuels over the period 2008-2023. The creation of the National Agency for the Development of Biofuels (ANADEB)[6] in 2009 was an essential tool for this strategy. Another reason why the government has been active in promoting this vegetal product these last years is that this feedstock does not directly compete with food supply. Although large-scale jatropha plantations look attractive from a project perspective, their indirect impacts on the economy and the environment are unknown. The economic and

[5] Pourghere is the French word for *Jatropha curcas L*. In English, this plant is called physic nut or purging nut. In Bambara (Mali), the usual term is *bagani*. In this article, we used jatropha, bagani and pourghère, wich are the common names in Mali.

[6] ANADEB was created in March 2009 with the mandate to: i) define technical and quality norms for biofuels, and monitor and evaluate these norms, ii) initiate research and development of biofuels, iii) train and support private operators in the field and iv) improve institutional frameworks for biofuels and ensure national and international partnerships.

environmental issues associated with jatropha, such as food security, energy dependency and the fight against soil erosion, could be significant. In terms of food security, the main concern is to maintain cereal production, which is the main staple of rural Malian households (République du Mali, 2008). There are major concerns that land and labor mobilization in the biofuel sectors would be taken away from the cereal production sectors, with considerable impacts on food. These concerns were in fact addressed in a June 2008 consultation, leading to a reflection on the risks and opportunities of the pourghère industry in the country and represented by the MaliFolke Center,[7] Mali Biocarburant SA,[8] Jatropha Mali Initiative (JMI)[9] and the Groupe Energies Renouvelables, Environnement et Solidarités (GERES)[10] (Pallière et al., 2009).

Thus, it is crucial to understand the impacts of biofuels, such as how they affect food prices in the long run. How would such a scaling up of biofuels affect the production of other tradable as well as non-tradable commodities? How would it alter the terms of trade? Would large-scale diversion of land for biofuel production help reduce poverty and inequality in Mali?

The overall objective of this study is to assess the economic development and environmental quality consequences of large-scale expansion of biofuels in Mali, one of the key producers of biofuels in Sub-Saharan Africa. This case study will help explain the potential gains and losses from the large-scale expansion of biofuels at the national level, taking into account the opportunity costs of resources and the overall impact on economic performance. The economy-wide impacts of the large-scale expansion of biofuels are modeled using a CGE model. The study assesses the overall impact of biofuel production on GDP, trade performance, prices, welfare and economic growth. Besides the impacts of expansion of biofuel production to meet domestic demand, this article also analyzes various scenarios related to biofuel production, consumption and trade. The distributional impacts of biofuels are modeled using a micro-simulation model. They are measured with a wide range of indices such as decomposable poverty indices and inequality indices. Pro-poor analyses are also presented to verify whether the simulated scenarios benefit or penalize the poorest Malian households. The Malian model includes 18 production sectors among which six are agricultural sectors, and 4,494 households from the household survey are included in the micro-simulation model. The approach will allow for all forms of household decomposition. In our model, we have taken into account the residential area of the household head (rural

[7] A Malian NGO following the initiative of a communal industry producing jatropha oil for rural electrical distribution (Garalo Commune).

[8] A private business producing biodiesel for the Malian transportation sector in partnership with the Union Locale des Sociétés Coopératives des Producteurs de Poughère (Koulikoro Cercle).

[9] A private business producing pure vegetable oil for the Malian industrial market, in partnership with the farmers of the Kita Cercle.

[10] A French NGO supporting a village industry producing oil in view of rural electrical distribution (commune of Yorosso).

versus urban) and distinguished the regions in which jatropha is produced. Finally, we have separated farm and non-farm households for our analysis.

In the next section, Mali's position in terms of biofuels is presented to provide some preliminary indications of results from the analysis presented in the latter part of the paper. Next, the main features of the micro-simulation computable general equilibrium model for the country are explained (section 3). In the fourth part, we describe the simulations performed, following with the macroeconomic and sectoral results (section 5), while section 6 is dedicated to the analysis of the distribution impacts of policies on Malian households. We conclude in the final section.

2 Biofuels in Mali: an overview

Since a few decades, Mali has been working on means to develop new alternative energy sources (alcohol biofuel and pourghère, etc.) by means of various projects and programs. Recently, Mali undertook a reform of its energy sector by setting up a national strategy for the development of biofuels. This strategy resulted in the establishment of a program for valuing pourghère cultivated areas (2004-2008),[11] the elaboration of the National energy policy[12] (2005) and the creation of the National agency for the development of biofuels (ANADEB) (2009). The jatropha industry is still in its beginnings, however. According to GEXSI (2008), very few projects in 2008 exceeded two years in length and involved significant oil production. Although there does not yet exist a market for the formal commercial exchange of jatropha and its oil, many countries including Mali are becoming aware of the potential of this plant in terms of producing green energy and substituting for hydrocarbons.

Jatropha: properties and uses

The pourghère plant belongs to the *Euphorbiaceae* family, whose seeds are believed to have been imported by the Portuguese from Central and South America in the 17th century. The shrub is frequently cultivated in hedges in order to fight against the water and wind erosion of soils and to protect agricultural crops from roving animals (Hennings, 2009). It was cultivated in the form of quickset hedges used as enclosures for cereal and vegetable gardens, particularly around villages. Another reason explaining the interest in pourghère is its resistance to drought, which is frequent in Mali. Indeed, this plant now grows in most of the planet's semi-desert regions that receive between 600-1000 mm annual rainfall and

[11] The Programme National de Valorisation Énergétique de la Plante Pourghère (PNVEP) comes within the scope of Malian policies and strategies presented in the Programme National d'Action Environnementale (PNAE), the Cadre Stratégique de Lutte contre la Pauvreté (CSLP) and the promotion of the Stratégie Nationale des Énergies Renouvelables. It is implemented by the Centre national de l'énergie solaire et des énergies renouvelables (CNESOLER) under the supervision of the Direction Nationale de l'Énergie of the ministère de l'Énergie, des Mines, et de l'Eau.

[12] The National energy policy aims to increase local production of energy by developing biofuels to satisfy the socioeconomic needs of the country at a lower cost.

experience long drought periods. It is cultivated using direct drilling of seeds, pricking out into pots (plant nurseries) or cuttage (Latapie, 2007).

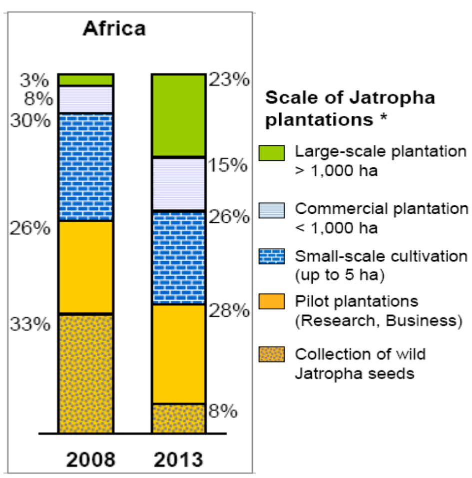
This plant has also been exploited since several decades to obtain oleaginous seeds containing between 20% and 40 % oil depending on the extraction method used (manual, mechanical or chemical) (Legendre, 2008). This oil can be used for lighting and cooking, as well as for producing soap, biocides, seed cakes or fuel (See Figure 4). It becomes a suitable diesel substitute for use in a wide range of stationary engines used in rural areas, such as irrigation pumps, mills and generators (Achten et al., 2008).

Jatropha around the world and in Mali

The cultivation of pourghère was introduced in Mali by French colonialists at the end of the 1930s in the Office du Niger and popularized in 1990s by the German development cooperation (GTZ). The plant came to be used as a barrier protecting agricultural areas from livestock (sheep, goats, etc.), soil erosion due to water run-off and wind, particularly in rural areas. It was also used by women as traditional medicine against malaria or general pain.

On a global scale in 2008, approximately 900,000 ha were counted, of which 85% were apparently planted in Asia (Indonesia, Myanmar, India, China). The shrub was thought to cover 120,000 ha in Africa, primarily in Madagascar, Zambia, Tanzania and Mozambique. By 2015, world production could approach 13 million hectares. In terms of Africa, Ghana and Madagascar alone may count 1.1 million of the two million hectares expected over the entire continent (GEXSI, 2008).[13] It is also interesting to note that farm sizes are on the increase. In 2008, only 11% of jatropha production in Africa was accounted for by large plantations. GEXSI (2008) predicts that in 2013, 38% of production on the continent will be accounted for by large farms, including 23% in plantations of more than 1000 hectares (Figure 1).

Figure 1: Development of Jatropha Schemes by 2013



Source: (GEXSI, 2008).

[13] These figures were estimated by the Global Exchange for Social Investment (GEXSI) sponsored by the World Wildlife Fund (WWF) to carry out a global market study on jatropha. The goal was to present the situation of jatropha cultivation in 2008 and to foresee the development of projects from now to 2015 for Latin America, Africa and Asia. (Cf. http://www.jatropha-platform.org/index.htm).

In 2002, Mali had at its disposal roughly 10,000 kilometers of jatropha shrubs, with a growth rate estimated at approximately 2,000 kilometers per year (Latapie, 2007). In 2008, consulted experts counted 1,800 hectares of pourghère shrubs, with an objective on the part of producers of reaching 23,000 hectares by 2015 (GEXSI, 2008). However, as mentioned in the agricultural report of the OECD and FAO (OCDE-FAO, 2009), African projects tied to the expansion of the industry are still modest in Africa.

In 2009, Pallière et al. estimated that the total cultivated surface reached 3,730 ha (Table 1) distributed in four significant production areas. The first place occupied *ex eaquo* by Kita and Koulikoro (34.5%) followed the history of these regions in the cultivation of quickset hedges of pourghère. Finally, the Yorosso and Garodo regions represent 31% of cultivated surfaces in the country.

Table 1: *Surface of cultivated pourghère in Mali*

Areas	Surface (ha) - 2008	%	# of producers	%
Kita	1 300,00	34,5%	1 313,00	42%
Koulikoro	1 300,00	34,5%	1 017,00	32%
Garalo	430,00	13%	530,00	17%
Yorosso	700,00	18%	300,00	9%
Total	**3 730,00**	**100%**	**3 160,00**	**100%**

Source: Pallière et al. (2009)

In Mali, the quest for transforming grain into biofuel is not a new concern, as it started in the beginning of the 20th century in the region of Segou (Haïdara, 1996). The properties of this biofuel are very close to those of some diesel fuels. Furthermore, the return of this plant is interesting, as it can reach 1,900 liters of oil per hectare versus 572 liters/ha with colza, 662 liters/ha with sunflower or 446 liters/ha with soya (Legendre, 2008).

Since pourghère production takes place on a small scale in Mali, the four previously cited areas appear to stand out clearly (Pallière et al., 2009).[14] In 2006, the Mali FolkeCenter developed a project targeting the production of jatropha oil in view of rural electrical distribution (generating sets) in the agricultural and cotton region of Garolo. Besides cotton, this region is also known for the production of peanuts and important food crops (corn, sorghhum, rice, etc.). In its project launched in 2007, Mali biocarburant SA used the properties of jatropha to produce biodiesel intended for the domestic market in the Koulikoro Cercle. This region, which stretches over 7,000 km^2, combines the production of commercial crops (cotton, peanut, and tabacco), food crops (corn, millet, rice) and truck farming thanks to its proximity to the Niger River. In the same year, the Jatropha Mali Initiative (JMI) project was also launched in Kita in the region of Kaye. The project initially targeted the production of biodiesel. Since 2009, jatropha vegetable oil destined for the Malian industrial market has become the first output resulting from this seed transformation. Finally, in 2008, the Groupe Énergies Renouvelables, Environnement et Solidarités (GERES) implemented a jatropha production project in the Koutiala Cercle for rural

[14] Cf. Figure 5 for a geographical overview of these jatropha production areas.

electrical distribution purposes.[15] Although, seen from this angle, jatropha production appears to be an interesting avenue for certain populations, the literature reveals an absence of consensus in terms of its concrete economic benefits. The question is whether expanding this type of production should be advocated or, on the contrary, the sector should be developed prudently.

Jatropha development: the controversy

Among the objectives most often associated with projects for developing jatropha cultivation, the advancement of women (production of soap and sale of oil), the reduction of village poverty (crop protection, sale of seeds, oil, soap), soil erosion control (planting of live shrubs) and the production of renewable energy are most often cited (Henning, 2009). Finally, impact analysis of introducing and developing this cultivation in rural settings on the welfare of households and communities is also beginning to generate growing interest in the current context of Millenium Development Goals (Pallière et al., 2009). Certain researchers such as Matthews (2007) see the production of biodiesel from jatropha as a means to industrialize poor countries and help them overcome poverty. Planted on a large scale, jatropha may even enable these countries to achieve energy autonomy, as well as increase their production and exportation. Renner (2007) well summarizes the perception of many as, according to her, "Jatropha seems to offer the benefits of biofuels without the pitfalls."

However, others question the production of biofuels from agricultural products. They raise concerns over biodiversity loss (Raizon, 2009) or endangering the food sovereignty of countries that are already struggling (Luoma, 2009; Raizon, 2009; Campa and Valentin, 2009). Other concerns include the possible influence of pourghère plantations on soil fertility or the risks of propagation of diseases or parasites that could annihilate not only jatropha but also other nearby cultures (Campa et al., 2009).[16] This literature shows that two clans are at odds when it comes to jatropha production. Nevertheless, as Benge (2006) states, "there is no indication that any scientific studies have been conducted to prove or disprove any of the above."

Based on the fact that the African continent still disposes of a significant volume of unexploited agricultural land (approximately 58% according to GEXSI, 2008), it appears relevant in our view to develop these rare analyzes, particularly in terms of examining welfare and food security. This is what we propose in the following sections through an analysis of the case of Mali.

[15] In our analysis, we will establish the existence of a jatropha production area in Mali based on these four projects.

[16] The authors would like to recall the African coffee plant (arabica) introduced to the entire intertropical area by colonists and whose plantations were decimated in the early 20th century by orange rust.

3 The Malian model

3.1 The data

The SAM was constructed with the main data drawn from an input–output table with 18 productive sectors.[17] The reference year for the SAM is 2006. We extracted the jatropha sector from the cash crop sector and the fuel sector was decomposed into fossil fuels and biofuels. We had to disaggregate them in order to focus our analysis on these sectors. Secondary data was used from various sources to decompose these sectors. The end result was a SAM with 20 production sectors. The next step was to link the micro-household data — 4,494 households from the 2006 *Enquête légère intégrée auprès des ménages* (ELIM-2006) survey — to the SAM. We modified the income and expenditure structures for the households based on the nomenclature of the SAM.

3.2 The model

Since the late 1990s researchers have been using CGE to analyze the impact of policy reforms on poverty and income distribution. Three main categories of these models have been used during this period: the representative household approach (RH), the integrated multi-household approach (IMH) and the multi-household sequential approach (MHS).

The CGE-RH approach divides households into groups, choosing a representative household for each group and using that representative household in the CGE model. The variations in income of the representative agents generated with the CGE model are applied to households within their respective group from a household survey. This assumption does not allow the analyst to take into account within-group changes in income distribution, even though studies (Huppi and Ravallion 1991 and Savard 2005, for example) have shown that such changes can be greater than between-group inequality changes. This is true both for the static measure and for variations following policy simulations. Savard (2005) demonstrated that the results of poverty and income distribution analysis can be completely reversed by taking into account within-group distributional effects.

To solve this problem, a second approach was proposed by Decaluwé, Dumont and Savard (1999) and applied by Cogneau and Robilliard (2000), Gørtz et al. (2000) and Cockburn (2001), namely the CGE integrated multi-household approach (CGE-IMH). This method incorporates a large number of households from a household survey (and sometimes all of them) into the CGE model. The approach takes into account within-group distributional effects and has the further advantage of providing coherence between the micro and macro parts of the model, but at a cost. First, data reconciliation can be very problematic (Rutherford, Tarr and Shepotylo, 2005); second, numerical resolution can be challenging (Chen and Ravallion, 2004).

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[17] The original input-output matrix was obtained from the "Direction nationale de la statistique et de l'informatique."

The third approach is referred to as the CGE micro-simulation sequential method (MSS) and could be subdivided into two variants. The first, micro-accounting, was formally presented by Chen and Ravallion (2004) and has been extensively applied in recent years.[18] The second variant, proposed by Bourguignon, Robilliard and Robinson (2005), consists of integrating, at an individual level, rich micro behavior observed at a household level such as consumption or labor supply. This version introduces more heterogeneity between households with the application of a microeconometric model. The general idea of the MSS approach is that a CGE module feeds market and factor price changes into a micro-simulation household model. The main criticism leveled at this approach is that the micro-feedback effect is not fully taken into account; the question has been raised in two literature reviews of macro-micro modeling for poverty analysis (Hertel and Reimer (2005) as well as Bourguignon and Spadaro (2005)). However, Bourguignon and Savard (2008) found that the loss of information associated with using the MSS approach can be relatively small and policy conclusions were robust between the two approaches.[19] In this paper we apply the micro-accounting version of the MSS approach.[20]

The last two approaches (IMH, MSS) allow for rich analysis of income distribution and poverty because they include a large number of households in the modeling exercise. This in turn allows the modeler to apply poverty and income distribution measures and indexes following policy simulations. As already mentioned, the IMH approach is the soundest on a theoretical basis. However, with this approach, it is necessary to construct a balanced sub-matrix for household accounts in a standard social accounting matrix. On the other hand, with the CGE-MSS approach, the household income and expenditure do not require balancing. This gain in flexibility comes from the fact that the micro module is solved sequentially and that we use price percentage changes to link the CGE module to the micro household module. This constraint has led us to select the CGE-MSS approach for our analysis. We will refer to the household sub matrix database as the household module. To capture the impact of jatropha and biofuel policies on the welfare of individual households and distributional effects, we had to adapt a standard model to specificities of these two sectors in the Malian economy. The presentation of the model is decomposed into the CGE module and household micro household module.

3.2.1 CGE module

The CGE component of our model (hereafter referred to as the CGE module) is based on the EXTER model of Decaluwé et al. (2001), with significant adjustments, which we will describe after presenting the main features of EXTER. The production structure is strongly

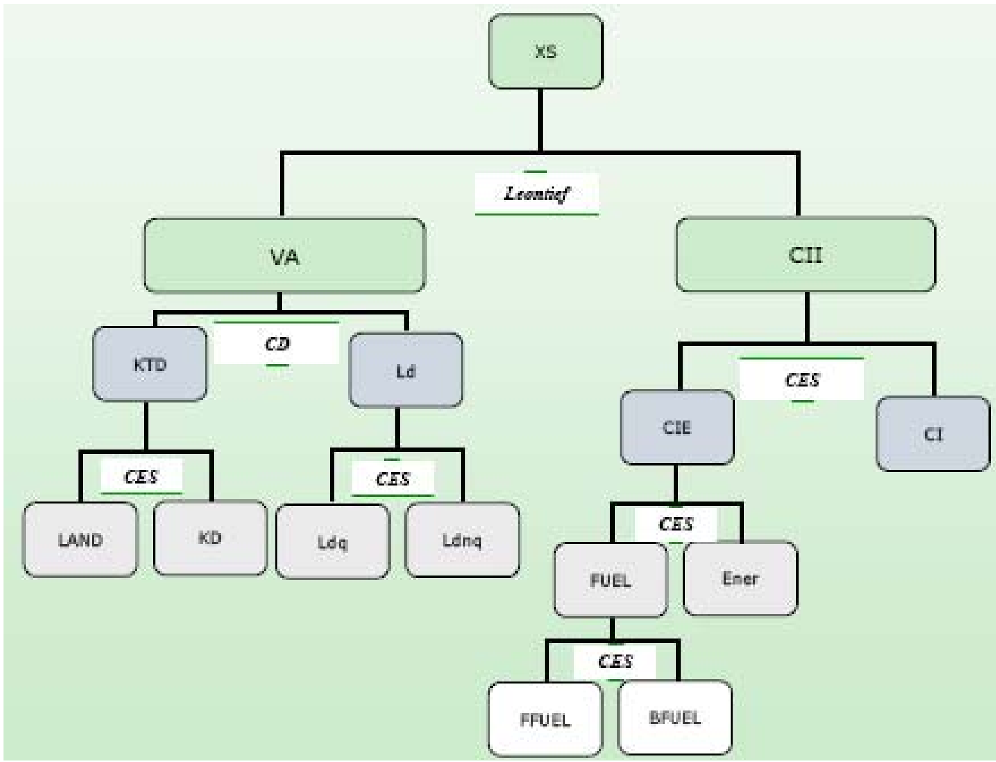
[18] Among early applications of this approach are Vos and De Jong (2003) and King and Henda (2003).

[19] Bourguignon and Savard's (2008) comparative analysis of the IMH and MSS approaches was applied to the Filipino economy. In this study, the labor supply was endogenous and the largest portion of the gap in the results obtained from the two approaches came from the labor supply. In our application, the labor supply will be held constant.

[20] The main reason for selecting this approach is the lack of adequate data to apply the microeconometric approach.

modified.[21] We present the multilayered production structure in the following graph to simplify the description.

Figure 2: The CGE model and its structure



Starting at the top level, we have total production of the sector (*XS*), which is made up of fixed value-added shares (*VA*) and intermediate consumption (*CII*), as generally assumed in standard CGE modeling. The relationship determining the level of *VA* is a Cobb-Douglas production function between composite labor (*LD*) and total capital (*KDT*). Producers minimize their cost of producing *VA* subject to the Cobb-Douglas function. First order conditions from this process are used to determine the optimal labor demand equations. Labor (*LD*) is then decomposed into skilled (*LDQ*) and unskilled (*LDNQ*) labor, with the combination of these two factors being determined by a constant elasticity of substitution (CES) function, once again through a process of cost minimization. This assumption implies that changes in the relative wages of the two types of labor will lead the producer to modify the ratio between the two groups of workers, subject to constraints on substitution linked to his production capacities. The total capital (*KDT*) is decomposed into land (*LAND*) and capital (*KD*). The same CES function is used to link these two factors.

The capital is sector-specific (fixed) and the land can be either mobile between agricultural sectors or fixed.[22] Moving on to intermediate consumptions, we significantly enrich the EXTER model by decomposing these inputs into various sub-inputs. We first have the total

[21] We provide the complete set of equations in the appendix.

[22] We will use the two assumptions in our simulations.

intermediate consumption (*CII*) that is decomposed into energy (*CIE)* and other intermediate consumptions (*CI)*. These two sub-inputs are linked with a CES function. The *CIE* is further decomposed into fuels (*FUEL*) and other energies (*ENER*). These two inputs are linked with a CES function, therefore allowing for substitution in these inputs. The fuels are further decomposed into fossil fuels (*FFUEL*) and biofuels (BFUEL) with the same functional form (CES). Other intermediate consumption (*CI*) was modeled as fixed shares from the input/output ratios calculated from the data in the SAM. This is a common practice with this type of model. The rich structure will allow biofuels to increase their market share to replace two types of energies as an intermediate input in the production processes of other sectors of the economy.

Sector-specific elasticities of substitution are used to reflect differences among sectors in determining the mix of factors in each CES function. We used higher elasticities for substitution between fossil fuels and biofuels compared to fuels and other energies. We allowed for this substitution as our review reveals various potential uses of biofuels as a source of energy.

As noted earlier, our model for Mali covers 20 production sectors, including jatropha, biofuels, fossil fuels and other energies (mainly electricity). Jatropha and biofuels were not found in the initial SAM (Coulibaly 2009). The size of these sectors is relatively small in Mali but they present substantial potential for growth.

In the model, four agents are modeled. First, the government draws its revenues from production taxes, import duties, households' and private firms' income taxes as well as from transfers from the rest of the world (budgetary assistance). Its expenditure is made up of the consumption of public services and of transfers to other agents. We have one agent representing aggregate private firms, which draw their income from capital income and pay taxes; they make transfers to other agents and save for investment. The rest of the world is considered as another agent in a standard fashion as it is used to model economic relations between Mali and the rest of the world including imports, exports and transfers to and from agents in Mali. Finally, we include a single representative household in the CGE module.

Ours is a model of a small open economy to which world prices of imports and exports are exogenous. We posed the Armington hypothesis (1969) for import demand, whereby domestic consumers can substitute domestically produced goods with imports (imperfectly) according to an elasticity of substitution that is sector specific. Where local consumers have no preference between imported and local goods, we use a high elasticity of substitution; conversely, the elasticity of substitution is low where consumers prefer one good over another.[23] The relative price of the two goods is the other determinant of the ratio of demand for imported goods versus demand for local goods. On the export side, producers can sell the goods on the local market or export their production and are influenced by

[23] Elasticities of substitution were selected after a consultation process with civil servants from the ministry of finances, statistics office and trade ministry.

relative prices on each market and by their respective elasticity of transformation of the good for one or the other market.

Our price equations are standard other than for utilities. We used the nominal exchange rate as a numeraire, and, as stated earlier, international prices (imports and exports) were exogenous. Accordingly, the country has no control over the prices applied on the world market.

Our model's equilibrium conditions are also standard. The commodity market is balanced by an adjustment of the market price of each commodity. The labor market is perfectly segmented and balances out with an adjustment of the nominal wage on each of the respective markets (skilled and unskilled). It is therefore possible for workers to move from one sector to another, but not from one market to another. Labor supply in each of the markets is fixed, and there is no unemployment.[24] The current account balance is exogenous, and is balanced with an adjustment of the endogenous price index (GDP deflator). With regard to the equilibrium of savings and investment, total investment adjusts to the sum of the savings of all agents in the model.

3.2.2 Micro Household module

In the micro household module, we include all of the 4,494 households from the survey (EMEP-II). We have specified income and expenditure functions for the households, which are parameterized on the household-specific information found in the survey. As mentioned, the module is solved sequentially (CGE module and household module). Let us now describe this sequence. We first specify an income equation that reflects income structure for each household in the EMEP--II survey. We assume that the endowments of factors are exogenous. We use the factor payment variations generated by the CGE module and apply them to the factor endowments. The two wage rates are also applied to labor endowments of households.[25] As in the CGE module, we assume that the transfers from other agents to the households are exogenous.

This procedure provides us with the new household-specific income. We can then move on to the expenditure side. The important component for welfare analysis is the change in household consumption. The demand functions are derived from a utility maximization process (Cobb-Douglas utility function), and this demand equation is a function of market prices and household income. The final step in the sequential resolution of the household module consists in computing the change in welfare. Implicitly, this allows us to take into account simultaneously the income and price effects on each household's welfare.[26] As in Bourguignon and Savard (2008), we use the variation of the real income to measure the

[24] This does not mean that we assume zero unemployment in the economy, but rather that unemployment is exogenous to the model.

[25] The survey included information that allowed us to decompose the labor into qualified and non qualified labor.

[26] This approach is different from the endogenous poverty line proposed by Decaluwé et al. (2005) as it captures the price effect of the simulation through specific household preference and not through a basic needs approach. For a discussion of the advantages and disadvantages of the two approaches, see Ravallion (1998).

change in welfare. The household-specific value shares for consumption are computed from observed figures in the survey. These shares are then used to specify a household-specific price index that is in turn used with the nominal income change to compute welfare changes.

3.2.3 Poverty and distributional analysis

After identifying the target[27] groups for the base period and simulations, the next step is to calculate and compare poverty and inequality indices. The indices chosen for poverty and inequality are de Foster, Greer and Thorbecke[28] (F-G-T, 1984) P_α and Gini, respectively. In addition to these indices, we applied pro-poor growth analysis.[29]

4 Simulations

We perform five main simulations with three variants of the first three simulations. Our first three simulations consist in increasing production of jatropha by providing new land for this purpose. We performed a fifteenfold increase in land for jatropha production going from 3,000 to 45,000 hectares. This is a large increase but it only represents 1% of the other agricultural land in Mali out of approximately 4 million hectares of exploited arable land. Three options are simulated. In the first option, the expansion of land is accomplished by using idle land and hence putting no pressure on other forms of agriculture. In the second scenario, we assume that the increase in production is generated by using half idle land and half from other agricultural sectors. In the third simulation, we assume that all the land required for the expansion of the jatropha sector will be taken from other agricultural sectors. This will provide us with upper and lower bounds for the increase in land use for jatropha production. In the next simulation (simulation 4a), we provide a subsidy of 20% to the biofuel production sector and in the last simulation, 4b, we combine this subsidy with simulation 1a. Simulations 1b, 2b and 3b are different than models 1a, 2a and 3a at the micro household model level. In the first scenarios, we assume that the expansion will be performed uniformly by farmers in the jatropha area—these are scenarios 1a, 2a and 3a—and in the second, the farmers of all regions will produce more jatropha or start producing jatropha. Table 2 summarizes these simulations.

[27] These groups have been identified in an effort to reflect the groups present in and outside of the Jatropha area, to assess impact on these groups and to compare their impacts on the other groups in the Malian economy. It should be noted that the different groups could very easily be introduced in our analysis.

[28] FGT poverty indices are additively decomposable; as such, they are interesting within the framework of this analysis and make it possible to measure the proportion of the poor among the population but also of this poverty depth and severity. The higher the degree of poverty aversion, the greater the importance granted to the poorest. For detailed information on this index family, read Ravallion (1994).

[29] A detailed version of this impact analysis will be based on three indices: the pro-poor growth index (PPGI) of Kakwani and Pernia (2001), the poverty equivalent growth rate (PEGR) of Kakwani and Son (2002), and the absolute rate of pro-poor growth of Ravaillion and Chen (2003) derived from the GIC. For a detailed presentation of these indices, see Boccanfuso and Ménard, 2008.

Table 2: Simulation description

Code	Simulation description
1a	15 times increase in agricultural land using idle land in jatropha area
1b	15 times increase in agricultural land using idle land in Mali
2a	15 times increase in agricultural land using 50% idle land in jatropha area and 50% agriculture land
2b	15 times increase in agricultural land using 50% idle land in Mali and 50% agriculture land
3a	15 times increase in agricultural land using 100% agriculture land
3b	15 times increase in agricultural land using 100% agriculture land
4a	20% subsidy funding by decrease in government expenditure
4b	20% subsidy funding by decrease in government expenditure & simulation 1a

5 Results

We proceed with a brief description of our macro and a few sectoral results. As we focus our analysis on a distributional impact of these scenarios, we select some key variables that play an important role in this distributional analysis.

5.1 Macroeconomic and sectoral impacts

From our results presented in Table 3 below, the first general statement we can formulate is that the impact on macro variables is relatively small. This is not surprising as the two main sectors of interest are relatively small at the reference period. The first simulation is the one with the weakest impact at the macro level. Hence, using idle land will have a slight positive impact on all macro variables. When the jatropha sector competes with other agricultural sectors for land, we observe a reduction in all macro variables. These effects are amplified with using all the land for expansion from other sectors. We also reiterate that the capital required by the jatropha sector will be drawn from other agricultural sectors. Hence, the competition comes from the land and capital side for other agricultural sectors. It is also important to mention that we assume fixed labor supply and hence, the expansion of one sector comes at the expense of the others.

The fourth simulation (4A) is interesting as it provides positive results for most variables. The only negative impact is for qualified wage, which is the result of layoffs in the public sector to fund the subsidy. Other variables increase with the other exception being the improvement of the current account deficit (a reduction in the deficit). We find the strongest positive impact on total investment, non-qualified wage and rental rate of agriculture. It is interesting to note the opposing impact on qualified wage that decreases and non-qualified wage that increases. This specific effect should benefit the poorer households versus the richer ones as the latter are more prevalent in the qualified market. The last simulation is quite similar to simulation 4A but with a slightly more positive impact on all variables except the current account balance and the non-qualified wage.

Table 3: Macro level results of the CGE model

Variables	Definition	Reference	Sim 1A	Sim 2A	Sim 3A	Simulation 4 (A & B) Biofuel Subsidy	Biofuel subsidy & 1A
Yh	Household income	3 206 350	0,01	-0,20	-0,42	0,04	0,05
w^1	qualifed wage	1	0,03	-0,05	-0,12	-0,70	-0,62
w^2	non qualifed wage	0,5	0,00	-0,29	-0,57	0,15	0,14
rr	rental rate of agricultural capital	1	0,03	-0,69	-1,41	0,09	0,11
Yg	Government income	826 370	0,01	-0,15	-0,31	0,00	0,00
Sg	Government savings	222 997	0,02	-0,56	-1,15	1,50	1,42
cab	current account balance	60 698	0,16	-1,23	-2,67	-2,62	-2,21
Ye	Firms' income	370 194	0,02	-0,19	-0,40	0,07	0,09
Se	Firms' savings	39 974	0,03	-0,39	-0,82	0,15	0,18
It	total investment	277 901	0,06	-0,74	-1,56	0,64	0,67
GDP	Gross domestic product	3 203 785	0,02	-0,22	-0,45	0,00	0,02

Moving on to the sectoral results, once again we have very limited impact with the exception of the jatropha and biofuel sectors. This is the result of the 15 fold increase in land use in the latter sector that produces more input for the biofuel sector at lower cost. Looking at the output/value added changes (in Table 4) we note that for the first simulations, the sectors decreasing output are the fossil fuels, and to a lesser extent the construction, public services and service sectors. Other sectors very slightly increase their production. In the second and third simulations, drawing land from other sectors has a stronger impact and these are negative for most sectors. However, the mining and manufacturing sectors as well as the public services increase their production. The third simulation produces stronger results. In these two simulations, the two sectors most negatively affected are the cotton and crop agriculture sector, and the livestock sector, the least negatively affected. For the last two simulations, we note that the subsidy is fairly efficient in generating an increase in output for the jatropha sector and biofuel sectors, which were both increased by more than 10%. The public sector is the one decreasing the most as this subsidy is funded by a reduction in public service provision. The price effects follow a similar trend with weak effects in general for all sectors but jatropha and biofuels, and weakest impact for simulation 1 and the strongest effects for simulation 4B.

Table 4: Macro and sectoral level results of the CGE model

Variables	Definition	Reference	Sim 1A	Sim 2A	Sim 3A	Simulation 4 (A & B)	
						Biofuel Subsidy	Biofuel subsidy & 1A
***Va* (value added)**	crop agriculture	417 259	0,00	-0,76	-1,52	0,00	0,00
	rice	162 704	0,02	-0,36	-0,74	-0,02	0,00
	export	40 896	0,02	-0,59	-1,19	0,01	0,03
	jatropha	850	90,06	89,79	89,51	10,37	110,23
	coton	173 224	0,02	-0,75	-1,51	0,17	0,17
	Livestock	315 643	0,02	-0,24	-0,50	0,02	0,04
	forestry	205 250	0,00	-0,61	-1,21	-0,02	-0,02
	mining	294 262	0,00	0,02	0,04	0,08	0,07
	agoindustry	280 422	0,00	0,01	0,02	0,03	0,03
	textile	96 402	0,01	0,03	0,05	-0,02	-0,01
	other industries	106 983	0,00	0,08	0,15	-0,03	-0,03
	other energy	172 527	0,00	-0,01	-0,02	0,01	0,01
	biofuel	127	84,93	84,71	84,48	10,83	105,66
	construction	203 715	-0,02	-0,15	-0,28	0,11	0,08
	commerce	173 017	0,00	-0,01	-0,03	0,00	0,01
	transport	84 833	0,01	0,01	0,01	0,04	0,05
	services	165 547	-0,01	-0,02	-0,04	0,00	-0,01
	banking & finance	21 700	0,00	-0,09	-0,17	0,09	0,08
	public services	251 456	-0,01	0,03	0,08	-0,38	-0,38
	fossil fuels	40 416	-0,05	-0,05	-0,05	-0,05	-0,10

As we can see from Table 5, the strongest impact is on jatropha (-77%); given the strong increase in supply, a drop in price is necessary for the economy to absorb this excess supply. Since this price decreases significantly and it is the main input to produce biofuel, this price also decreases by 39% for the first three simulations. For the fourth simulation (4A), the price of biofuels decreases by close to 8% and as a result of the subsidy, this increase in competitiveness allows the sector to increase its output by almost 11%. This increase in production will require an increase in demand for jatropha and given the fixed land assumption, this leads to a strong increase in the price of jatropha of 15%. When we combine this simulation with the 1A simulation we greatly reduce the demand side pressure on jatropha and find almost the same decrease in the price of jatropha. The two simulations combined amplify the pressure on the price of biofuels with a decrease just greater than 43%. It is also interesting to note that the market prices of other agricultural goods all increase as a result of any one of the simulations performed.

Table 5: Macro and sectoral level results of the CGE model

Variables	Definition	Reference	Sim 1A	Sim 2A	Sim 3A	Simulation 4 (A & B)	
						Biofuel Subsidy	Biofuel subsidy & 1A
***Pq* (market price)**	crop agriculture	1.001	0,02	0,50	0,98	0,11	0,12
	rice	1.008	-0,01	0,18	0,38	0,02	0,01
	export	1.007	0,02	0,40	0,78	0,04	0,06
	jatropha	1.000	-77,46	-77,51	-77,55	14,99	-76,96
	coton	1.025	0,01	0,11	0,20	0,16	0,16
	Livestock	1.002	-0,01	0,01	0,02	0,05	0,04
	forestry	1.001	0,01	0,36	0,71	0,04	0,06
	mining	1.000	0,01	-0,08	-0,16	-0,02	-0,01
	agoindustry	1.047	0,00	-0,14	-0,28	-0,06	-0,05
	textile	1.064	0,01	-0,23	-0,47	0,08	0,08
	other industries	1.030	0,00	-0,05	-0,09	-0,01	-0,01
	other energy	1.076	0,00	-0,30	-0,60	0,09	0,08
	biofuel	1.000	-38,81	-39,03	-39,24	-7,94	-43,63
	construction	1.051	-0,01	-0,25	-0,50	0,11	0,09
	commerce	1.328	0,04	-0,39	-0,83	0,09	0,13
	transport	1.220	0,01	-0,12	-0,25	-0,01	0,00
	services	1.027	-0,01	-0,24	-0,47	0,02	0,01
	banking & finance	1.286	-0,01	-0,21	-0,41	-0,18	-0,18
	public services	1.000	0,02	-0,11	-0,23	-0,41	-0,36
	fossil fuels	1.016	-0,01	-0,21	-0,42	0,03	0,02

We complete this section with a look at the rental rate of capital for the non agricultural sectors (Table 6). Since the capital is fixed, each sector has a specific rental rate of capital. In the first simulation, most sectors do not experience noticeable changes in the rental rate of capital. The strongest changes are for fossil fuels (a competitor of biofuels), the transportation sector (an important consumer of fuel), commerce and construction sectors. As for other variables, simulations 2A and 3A produce stronger effects. In the third simulation we observe a few variations greater than 1% in absolute terms with a decrease of 1.45% in the construction sector and a 1.05% decrease in the commerce. The subsidy (simulation 4A) produces a positive impact on the biofuel sector but with a much smaller impact compared to the first three simulations. The last simulation produces a very high impact on the biofuel sector. Such an increase in capital return should generate major investment in the sector in the future but we do not capture this as we have a static model. This increase in investment would significantly reduce the returns in this sector.

Table 6: Macro and sectoral level results of the CGE model

Variables	Definition	Reference	Sim 1A	Sim 2A	Sim 3A	Simulation 4 (A & B)	
						Biofuel Subsidy	Biofuel subsidy & 1A
r (rental rate of capital)	mining	1	-0,01	0,10	0,20	0,07	0,06
	agoindustry	1	0,01	-0,17	-0,35	-0,09	-0,07
	textile	1	0,02	-0,22	-0,45	0,06	0,08
	other industries	1	0,00	0,04	0,08	-0,13	-0,13
	other energy	1	0,00	-0,31	-0,63	0,10	0,10
	biofuel	1	541,88	538,32	534,73	36,13	782,91
	construction	1	-0,05	-0,75	-1,45	0,47	0,39
	commerce	1	0,06	-0,49	-1,05	0,13	0,18
	transport	1	0,14	0,09	0,05	0,01	0,15
	services	1	-0,04	-0,36	-0,68	0,11	0,07
	banking & finance	1	0,02	-0,30	-0,62	-0,41	-0,36
	public services	1	0,00	0,00	0,00	0,00	0,00
	fossil fuels	1	-0,15	-0,22	-0,30	-0,80	-0,90

We will follow this section with the distributional analysis. It will be important to keep in mind the variations presented in the previous tables. Moreover, as we have described in the introduction of this section, we apply two sub scenarios in the microhousehold in which we assume in simulations A that the expansion of jatropha production is done in the jatropha area whereas in the simulations B the increase is applied proportionally to all farm households in the survey.

5.2 Distributional impacts

In this section, we present and analyze poverty and income distribution changes following the different policy scenarios. The data here used has been drawn from the 2006 *Enquête Légère Intégrée auprès des ménages* (ÉLIM) involving 4,494 households across the Malian territory. We perform this analysis at the national level and decompose households based on three criteria. We first distinguished between farm and non-farm households. To introduce greater heterogeneity, we then distinguished between households located in areas in which several jatropha production projects have been implanted and others.[30] Finally, we distinguished between rural and urban households. In both the microsimulation model and the welfare analysis, we have thus carried out our work based on eight household groups: 1) Farm households living in the urban area where jatropha is produced (MAJU); 2) Non-farm households living in the urban area where jatropha is produced (MNAJU); 3) Farm households living in the rural area where jatropha is produced (MAJR); 4) Non-farm

[30] We have based this identification on Pallière et al. (2009).

households living in the rural area where jatropha is produced (MNAJR); 5) Farm households living outside the urban area where jatropha is produced (MANJU); 6) Non-farm households living outside the urban area where jatropha is produced (MNANJU); 7) Farm households living outside the rural area where jatropha is produced (MANJR); 8) Non-farm households living outside the rural area where jatropha is produced (MNANJR). Table 7 presents the share of households as well as average per capita expenditure for each of the eight groups. We can observe that 10.15% of Malian households live in the area where jatropha cultivation is already active. In addition, we can see that the average per capita expenditure of urban households, whether living in the jatropha area or not, is higher than the national average, with the exception of farm households living in the urban jatropha area (MAJU).

Table 7: Descriptive statistics for groups

	GROUPS		% of households	Mean of *per capita* expenditure (Fcfa)
1	MAJU	Farm households in urban jatropha area	0,56%	237 217.70
2	MNAJU	Non-farm households in urban jatropha area	2,86%	709 975.90
3	MAJR	Farm households in rural jatropha area	4,93%	182 660.62
4	MNAJR	Non-farm households in rural jatropha area	1,48%	257 064.47
5	MANJU	Farm households outside urban jatropha area	4,28%	333 356.14
6	MNANJU	Non-farm households outside urban jatropha area	29,68%	673 909.07
7	MANJR	Farm households outside rural jatropha area	40,51%	198 252.09
8	MNANJR	Non-farm households outside rural jatropha area	15,71%	305 907.32
	MALI		100%	377 035.72

Sources: Elim, 2006

Let us begin with a brief analysis of poverty and inequality for the reference situation at the national level and for the eight groups of interest (Figure 3).[31] While poverty at the national level is slightly inferior to 40%, the jatropha area is revealed to be the poorest in Mali for the whole of Malian households with the exception of the group of non-farm households living in urban areas (MNAJU), which in fact proves to be the least poor of the groups (10.43%). Farm households living in rural jatropha areas (MAJR) are, conversely, the most affected by poverty (51.27%). Finally, it should be noted that the poverty of households living outside the jatropha production area is systematically weaker than national poverty. It will be interesting to see whether the simulated policies will attenuate this difference. We should add that the same results can be observed for indices of depth (FGT1) and severity (FGT2).

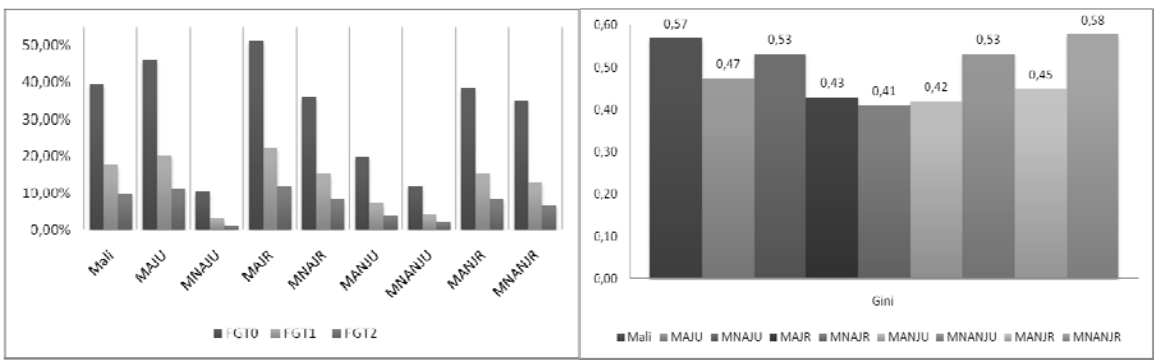
[31] The welfare indicator used is that of annual expenditures following private net transfers (monetary and non monetary), expressed per capita. The literature shows that income transfers between households can be considered a source of poverty reduction as well as a means to attenuate inequalities between households (Adams and He, 1995). Coulibaly (2010) shows that in the absence of transfers, poverty would be much higher in Mali and its regions.

It is also worth noting that the national threshold chosen is the one suggested by the World Bank, based on the basic needs methodology. The four other thresholds were obtained using averages based on regional urban and rural thresholds while taking into account both jatropha producing areas and others. Table 10 of the appendix presents the thresholds used.

Mali proves to be a country with significant inequality (0.57). The only group with a higher Gini index is that of non-farm households living outside the jatropha area and in an urban setting (MNANJR). The two groups of non-farm households living in an urban area (MNAJU and MNANJU) and in which the poverty incidence is the weakest (respectively 10.43% and 12.02%) are in fact the groups marked by strong inequality (0.53). The whole of groups containing farm households (MAJU, MAJR, MANJU and MANJR) have Gini indices varying between 0.43 and 0.47 below national inequality. Finally, the group of non-farm households living in the jatropha production area in a rural setting (MNAJR) proves to be the least unequal.

Figure 3: Poverty and inequality analysis for Mali and the groups

(a) (b)



Source: Resutlts obtained by authors with DASP 2.1

With regard to the impact of simulations on national poverty, we can see that Mali would experience a very slight increase in poverty when the country would choose to increase the quantity of land devoted to jatropha production (Table 8). Only a 20% subsidy in the biofuel sector (Sim 4A) would have a beneficial effect, albeit a modest one, on poverty incidence (-0.15%). However, this effect is cancelled when the subsidy is accompanied by an increase in jatropha production via an increase in the *land* factor. The improvement achieved with the establishment of a subsidy in the biofuel sector is a consequence of the jatropha prix increase of almost 15%, while the other simulations insinuate a decrease. Moreover, the generalized decrease in the prix of biofuels is much weaker with the subsidy policy.

When analyzing the impact of the policies on the targeted groups, we observe that only two of these groups experience changes in terms of poverty.[32] The group of farm households living in the urban jatropha area proves to be the primary beneficiary of the increase in land destined for jatropha production. Indeed, the incidence of poverty would decrease between 8.57% and 12.85%. This result is consistent with expectations since the households will be able to exploit more land for jatropha production, which is confirmed by the increase in its value added (Table 4). We are, however, aware of the limits of this result since this group of households is the smallest and represents 0.56% of Malian households.

[32] The obtained results can be observed for the three poverty indices used.

Table 8: Variation of poverty indices by groups

		Mali	MAJU	MNAJU	MAJR	MNAJR	MANJU	MNANJU	MANJR	MNANJR
Base	FGT0	39,72	46,09	10,43	51,27	35,73	20,09	12,02	38,59	34,93
	FGT1	17,42	20,17	3,19	22,31	15,32	7,40	4,26	15,29	13,06
	FGT2	9,96	11,30	1,22	12,06	8,11	4,03	2,24	8,17	6,61
Sim 1A	Δ% FGT0	0,06	-12,85	0,00	1,81	0,00	0,00	0,00	0,00	-0,33
	Δ% FGT1	*0,28*	-12,26	*-0,05*	*5,45*	*-0,02*	*-0,02*	*-0,03*	*-0,02*	*-0,03*
	Δ% FGT2	*0,41*	-12,36	*-0,08*	*7,54*	*-0,03*	*-0,02*	*-0,03*	*-0,03*	*-0,03*
Sim 1B	Δ% FGT0	0,06	-12,85	0,00	1,81	0,00	0,00	0,00	0,00	-0,33
	Δ% FGT1	*0,28*	-12,26	*-0,05*	*5,46*	*-0,02*	*-0,02*	*-0,03*	*-0,02*	*-0,03*
	Δ% FGT2	*0,41*	-12,36	*-0,08*	*7,55*	*-0,03*	*-0,02*	*-0,03*	*-0,03*	*-0,03*
Sim 2A	Δ% FGT0	0,04	-8,57	0,00	*4,44*	0,00	0,00	0,00	0,00	0,06
	Δ% FGT1	*0,22*	-12,04	-0,56	*6,76*	*-0,28*	*-0,16*	*-0,33*	*-0,24*	*-0,19*
	Δ% FGT2	*0,35*	-12,12	-0,92	*9,32*	*-0,46*	*-0,20*	*-0,34*	*-0,25*	*-0,25*
Sim 2B	Δ% FGT0	0,03	-12,85	0,00	1,81	0,00	0,00	0,00	0,00	0,06
	Δ% FGT1	*0,26*	-12,22	-0,56	*5,47*	*-0,28*	*-0,01*	*-0,33*	0,02	*-0,19*
	Δ% FGT2	*0,37*	-12,30	-0,92	*7,56*	*-0,46*	*0,00*	*-0,34*	*0,03*	*-0,25*
Sim 3A	Δ% FGT0	0,08	-8,57	0,00	*5,08*	3,37	0,00	0,00	0,31	-0,16
	Δ% FGT1	0,14	-11,76	*-1,07*	*7,95*	*-0,55*	-0,30	*-0,63*	*-0,46*	*-0,37*
	Δ% FGT2	0,27	-11,91	-1,78	*10,87*	*-0,89*	*-0,38*	*-0,67*	*-0,48*	*-0,48*
Sim 3B	Δ% FGT0	0,04	-12,85	0,00	1,13	3,37	0,00	0,00	0,44	-0,16
	Δ% FGT1	*0,23*	-12,17	*-1,07*	*5,49*	*-0,55*	0,05	*-0,63*	*-0,07*	*-0,37*
	Δ% FGT2	*0,33*	-12,23	-1,78	*7,56*	*-0,89*	0,02	*-0,67*	*0,08*	*-0,48*
Sim 4A	Δ% FGT0	*-0,15*	-12,85	0,00	-1,20	0,00	0,00	0,00	0,00	-0,33
	Δ% FGT1	*-0,21*	-13,29	-0,12	*-1,65*	*-0,07*	0,73	0,02	*-0,03*	-0,01
	Δ% FGT2	*-0,24*	-13,29	-0,25	*-2,11*	*-0,10*	0,08	-0,01	-0,02	-0,01
Sim 4B	Δ% FGT0	0,03	-12,85	0,00	1,20	0,00	0,00	0,00	0,00	-0,33
	Δ% FGT1	*0,27*	-12,28	*-0,17*	*5,43*	*-0,09*	0,05	-0,05	*-0,06*	-0,03
	Δ% FGT2	*0,39*	-12,34	*-0,32*	*7,51*	*-0,13*	0,05	-0,02	*-0,05*	-0,04

Conversely, the group of farm households living in the rural part of the jatropha area (MAJR) proves to be the loser when it comes to simulated measures with the exception, again, of the subsidy policy in the biofuel sector. The decrease in the price of jatropha largely explains this result, since farm households see their income diminished by this price decrease. The last group for which we observe slight improvements in poverty indices is that of non-farm households living in rural areas but outside the jatropha production area (MNANJR). This is explained by the increase observed in per capita expenses obtained for this household group.

For the other groups, the effects of the simulations are virtually inexistent, including for simulation 4A (subsidy in the biofuel sector). It is nevertheless interesting to observe that regardless of the source of increase of land destined for jatropha production, the effect on poverty incidence is nil. This could imply that even if there is substitution in agricultural production between jatropha and another type of agriculture (as for simulations 2 and 3), the households of these groups would not be negatively affected.[33]

Table 9 presents the effects of the five groups of simulations on inequalities. The simulated policies all have a slightly negative effect on Malian inequality. Thus, as new lands destined for jatropha production are substituted for lands used for other purposes (simulations 1, 2 and 3), we observe an increase in the Gini index. Even if this increase is miniscule (between 0.08% and 0.12% increase), this result must be considered in the eventuality that measures would be taken to promote jatropha production in Mali.

Table 9: Variation of Gini index by groups

	Mali	MAJU	MNAJU	MAJR	MNAJR	MANJU	MNANJU	MANJR	MNANJR
Gini	0,57	0,47	0,53	0,43	0,41	0,42	0,53	0,45	0,58
Δ% Sim 1A	*0,077*	*11,088*	0,002	-0,255	-0,001	0,000	0,003	-0,004	0,002
Δ% Sim 2B	0,077	*11,088*	0,002	-0,255	-0,001	0,000	0,003	-0,004	0,002
Δ% Sim 2A	*0,091*	*10,918*	*0,027*	-0,292	-0,010	0,041	-0,010	0,004	0,015
Δ% Sim 2B	0,098	*11,144*	*0,027*	-0,281	-0,010	0,049	-0,010	0,003	0,015
Δ% Sim 3A	*0,103*	10,783	0,053	-0,318	-0,018	0,083	-0,018	-0,008	0,030
Δ% Sim 3B	*0,120*	*11,202*	0,053	-0,308	-0,018	0,098	-0,018	-0,007	0,030
Δ% Sim 4A	*0,024*	*12,414*	0,000	0,158	0,001	0,005	-0,004	-0,016	0,007
Δ% Sim 4B	0,068	*10,680*	0,001	*-0,248*	0,000	0,005	-0,007	-0,015	0,062

In terms of the effects on the groups, the results obtained are consistent with those found for poverty since the two most affected groups are farm households living in the urban jatropha area (MAJU) and farm households living in a rural jatropha area (MAJR). The former (MAJU) will experience a growth of inequality greater than 10% regardless of the simulation, thus approaching the inequality observed among non-farm households in this area (MNAJU). For farm households living in the rural part of the jatropha area (MAJR), the increase in jatropha production results in a slight decrease in inequalities. Only the presence of the subsidy (Sim 4A) would have a negative effect on the income distribution of these households. As for poverty, the effects of the simulations on inequality are virtually inexistent for the other groups.

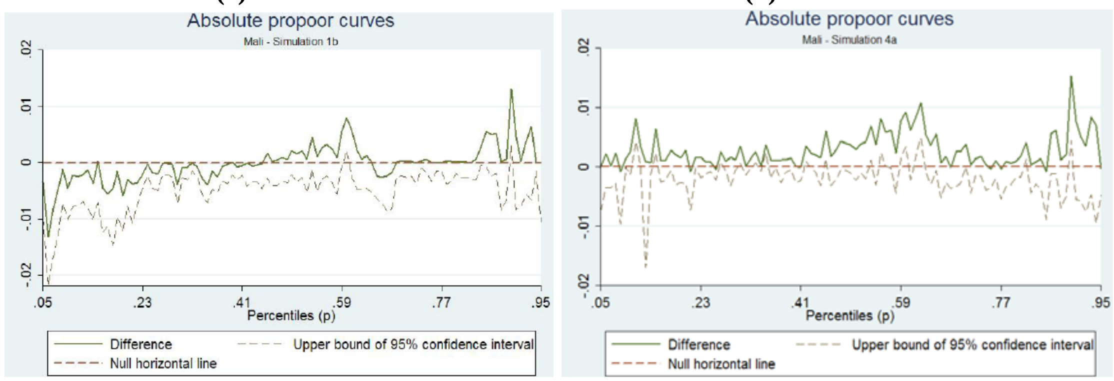
5.3 Pro-poor analysis

To complete our impact analysis, we have examined whether the suggested simulations could be considered by policies given their pro-poor nature. To conduct this analysis, we have used the growth incidence curve (GIC) developed by Ravallion and Chen (2003). This analysis allows us to see whether the economic growth generated by the model is redistributed to the poorest centiles.

[33] Sensitivity analyzes will have to be conducted in a revised version to support this point.

Figure 4: Growth incidence curve for Mali

(a) Simulation 1B **(b) Simulation 4A**

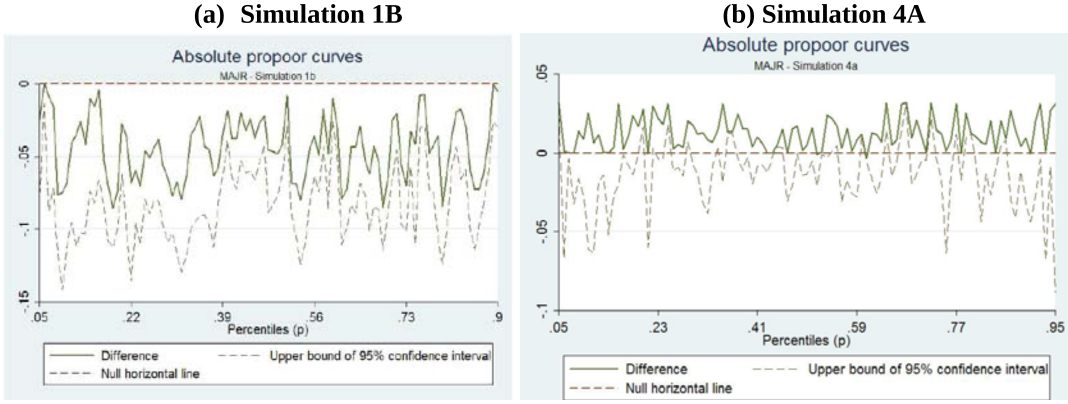


Source: Computed by authors from ELIM 2006 with DASP package

Figure 4(a) presents this GIC for Mali when the quantity of land destined for jatropha production was multiplied by 15 based on non-cultivated lands (Sim 1B). We should recall that we had observed an increase in national poverty and an exacerbation of poverty following this simulation. GIC analysis shows us that this measure would tend to be pro-rich since the first centiles would experience a decrease in their average income while the 50 last centiles would tend to see an increase in their average income. When we replicate the analysis based on the establishment of a subsidy in the biofuel sector (Sim 4A), we observe that all centiles benefit from an increase in average income. Households between the 40th and 70th centiles would be those benefiting most from this measure. In this case, it is nevertheless difficult to talk about a pro-poor or pro-rich measure.

Figure 5: Growth incidence curve for MAJR

(a) Simulation 1B **(b) Simulation 4A**



Source: Computed by authors from ELIM 2006 with DASP package

Figure 5 represents the GIC for the group of farm households living in the rural jatropha area, which is the poorest group of households (51.27%). Increasing jatropha production land led to an increase in poverty and a slight decrease in inequalities in this group. The GIC[34] shows us that this measure has a negative effect on all centiles but does not allow us

[34] We should add that very similar curves are obtained for all simulations with the exception of simulation 4A.

to conclude concerning the pro-poor nature of the policy. Only simulation 4A shows an improvement in average income for all households of the group. Nevertheless, this result does not enable us to think that this measure would allow for reducing poverty among the poorest of this group.

This analysis of pro-poor growth based on measures for increasing jatropha production in Mali via increasing the *land* factor leads us to conclude that this mechanism would not allow for reaching the objective of reducing poverty. We have found that subsidizing the biofuel sector would be preferable at the national level as well as for most groups. This measure proves to be insufficient, however, due to its weak effect on poverty and inequalities. The analysis of pro-poor growth confirms that the means would be interesting for the Malian economy but its extent would be insufficient.

6 Conclusion and recommandations

In the paper, we construct a CGE model with a microsimulation model to analyze the distributional impact of the expansion of the jatropha and biofuel sectors in Mali. We also provide macro and sector effects of such scenarios. Given the small initial size of the sector, we show that a significant expansion of the sector will not produce a major negative impact on other agricultural sectors. Our preliminary results also seem to show that the expansion of the sector is not very efficient to achieve the goal of reducing poverty. Some groups directly concerned seem to benefit but other are losers and poverty increases at the national level. The only scenario producing positive results at the national level is the subsidy to biofuel funded by a reduction in the production of public services. It is also interesting to observe that the origin of the land used for expending production is not a key element to contribute to our findings. Hence, using idle land or competing with other sectors produces a similar poverty impact.

Further scenarios will need to be analyzed and sensitivity analysis performed to see how robust these results are to changes in closure of the current account balance and some key elasticities in our model, such as the degree of substitution between inputs in production, trade elasticities. In concluding we will emphasize the importance of such an analysis in a CGE microsimulation context even with the relatively small size of the jatropha and biofuel sectors. Our results reveal that policy scenarios performed on two sectors that contribute less than 0.5% can produce a significant distributional impact. The links between these sectors and the rest of the economy allow us to identify interrelations between a scenario and poverty and income distribution changes. Further analysis is nevertheless required to increase the confidence we can have in these conclusions.

7 Bibliography

Achten, W. M. J., L. Verchot, Y. J. Franken, E. Mathijs, V. P. Singh, R. Aerts and B. Muys, (2008), "Jatropha bio-diesel production and use", *Biomass and Bioenergy*, Vol 32(12), pp. 1063-1084.

Adams, R. H. Jr. and J. J. He, (1995), "Sources of income inequality and poverty in rural Pakistan", Research reports 102, International Food Policy Research Institute (IFPRI).

Baier, S. L., M. Clements, C. W. Griffiths, and J. E. Ihrig, (2009), "Biofuels Impact on Crop and Food Prices: Using an Interactive Spreadsheet", FRB International Finance Discussion Paper No. 967. Available at SSRN: http://ssrn.com/abstract=1372839.

Benge, M., 2006. "Assessment of the potential of *Jatropha curcas*, (biodiesel tree) for energy production and other uses in developing countries", ECHO's website: 2006. Available at http://www.echotech.org/mambo/index.php?option=com_docman&task=doc_view&gid=179&Itemid=68.

Boccanfuso, D. and C. Ménard, (2008), "La croissance pro-pauvre : un aperçu exhaustif de la « boite à outils » ", Cahier de recherche du GRÉDI #09-06, Université de Sherbrooke, Québec, Canada.

Bourguignon F., A. S. Robilliard, and S. Robinson. (2005). "Representative Versus Real Households in the Macroeconomic Modeling of Inequality." In T. J. Kehoe, T.N. Srinivasan, and J. Whalley (eds.), *Frontiers in Applied General Equilibrium Modeling*. Cambridge: Cambridge University Press.

Bourguignon, F. and A. Spadaro. (2005). "Microsimulation as a Tool for Evaluating Redistribution Policies." *Journal of Economic Inequality*, 4(1): 77-106.

Bourguignon F. and L. Savard (2008). Distributional Effects of Trade Reform: An Integrated Macro-Micro Model Applied to the Philippines in Bourguignon, F., M. Bussolo, and L.A. Pereira da Silva, (eds.) "The Impact of Macroeconomic Policies on Poverty and Income Distribution: Macro-Micro

Brittaine R. and N. Lutaladio, (2010), "Jatropha: A Smallholder Bioenergy Crop - The Potential for Pro-Poor Development", FAO Integrated Crop Management Vol. 8, 116 pg ISBN: 9789251064382. Available at: http://www.fao.org/docrep/012/i1219e/i1219e.pdf.

Campa, C. and C. Valentin, (2009), "Le jatropha, une plante miracle?" in Sciences au Sud n°49 – Tribune. Available at: http://www.ird.fr/content/download/7330/76701/version/1/file/sas49_tribune.pdf.

Chen, S. and M. Ravallion. (2004). Welfare Impacts of China's Accession to the World Trade Organization. *World Bank Economic Review* 18(1): 29–57.

Cockburn, J. (2001). "Trade Liberalization and Poverty in Nepal: A Computable General Equilibrium Microsimulation Analysis." Working paper 01-18, CREFA, University of Laval, Québec.

Cogneau, D. and A.-S. Robilliard. (2000). "Income Distribution, Poverty and Growth in Madagascar: Micro Simulations in a General Equilibrium Framework." IFPRI TMD Discussion Paper 61, International Food Policy Research Institute, Washington, DC.

Coulibaly M., (2010), "Croissance économique et dynamique de la pauvreté", Cahier du GREAT, Bamako.

Decaluwé, B. J.-C. Dumont, and L. Savard. (1999). "How to Measure Poverty and Inequality in General Equilibrium Framework." Working Paper 9920, CREFA, University of Laval, Québec.

Decaluwé, B., A. Martens, and L. Savard. (2001a). "*La politique economique du développement et les modèles d'equilibre général calculabl*"*e*. Montréal: Montréal University Press.

Dornbosch R. and R. Steenblik (2007), *Biofuels: Is the cure worse than the disease?* OECD, Round Table on Sustainable Development, Paris, 11-12 September 2007, [SG/SD/RT(2007)3/REV1], Organisation for Economic Development and Cooperation (OECD), Paris.

Fargione, F.; Hill, J.; Tilman, D.; Polasky, S. and Hawthorne, P., (2008), "Land clearing and the biofuel carbon debt", *Science* Vol. 319, pp. 1235 – 1238.

Foster (J.), (J.) Greer et (E.) Thorbecke, 1984 - « *A class of Decomposable Poverty Measures* », Econometrica, 52(3).

GEXSI, (2008), *Global Market Study on Jatropha. Final Report*. Prepared for the World Wide Fund for Nature (WWF). London/Berlin: Global Exchange for Social Investment.Available at: http://www.jatropha-platform.org/index.htm.

Gørtz, M., G. Harrison, C. Neilsen, and T. Rutherford. (2000). Welfare gains of extending opening hours in Denmark. Economic working paper B-00-03, University of South Carolina, Darla Moore School of Business, Columbia, South Carolina.

Haïdara, A., O., (1996), "Valorisation d'une huile végétale tropicale : l'huile de pourghère », Mémoire de maîtrise es sciences appliquées, Génie Chimique, Université de Sherbrooke. Available at: http://www.phpage.fr/bioenergies/doc/hvc-mq21766.pdf.

Headey D. and S. Fan, (2008), "Anatomy of a crisis: the causes and consequences of surging food prices", *Agricultural Economics*, Vol. 39, supplement, pp. 375–391.

Henning, R.,K., (2009), "The Jatropha System – an integrated approach of rural development", Weissensberg, Germany. Available at:

http://www.jatropha.de/documents/The%20Jatropha%20Book-2009.pdf.

Hertel, T., and J. Reimer. (2005). "Predicting the poverty impacts of trade reform, " *Journal of International Trade & Economic Development*, 14(4), pp. 377-405.

Hill, J., E. Nelson, D. Tilman, S. Polasky, and D. Tiffany. (2006), "Environmental, economic, and energetic costs and benefits of biodiesel and ethanol biofuels", Proceedings of the National Academy of Science 103: 11206–11210.

Huppi, M., and M. Ravallion. (1991). "The Sectoral Structure of Poverty During an Adjustment Period: Evidence for Indonesia in the Mid-1980s". *World Development* 19(2): 1653–1678.

King, D., and Handa S. (2003). "The welfare effects of balance of payments reforms: A macro-micro simulation of the cost of rent-seeking.? " *The Journal of Development Studies*, 39(3): 101-128.

Mathews, J., (2007), "Prospects for a biofuels industry in Australia", MGSM working papers in management, Macquarie University. Graduate School of Management, no. 13.

Mitchell, D., (2008)," A Note on rising food prices", The World Bank, Development Prospects Group, Policy research working paper #4682.

Latapie, R., (2007), "La culture du pourghère : une activité génératrice de revenus qui permet de faire face aux enjeux énergétiques du Mali. Le cas du projet Garalo Bagani Yelen", Université de Rennes 1 et MaliFolkcenter, 107 pages. Available at: http://www.riaed.net/IMG/pdf/La_culture_du_pourghère_au_Mali_0108.pdf.

Legendre, B., (2008), "Jatropha Curcas (Tabanani) : Note agronomique", Technologies for hman development, Dakar, Senegal. Available at: http://www.riaed.net/IMG/pdf/Article_Culture_du_Jatropha_Curcas_080611.pdf.

Luoma J. R., (2009), "Hailed as a Miracle Biofuel, Jatropha Falls Short of Hype", Yale Environment 360, publication of the Yale School of Forestry & Environmental Studies. Avalaible at: http://e360.yale.edu/content/feature.msp?id=2147.

Rising Food Prices", Policy Research Working Paper No. 4682, The World Bank, Washington, DC.

OECD, (2008), "Biofuel Support Policies: An Economic Assessment ", Available at http://puck.sourceoecd.org/vl=1884709/cl=13/nw=1/rpsv/cw/vhosts/oecdthemes/99980002/v2008n12/contp1-1.htm.

OECD-FAO, (2009), "Agricultural Outlook 2009-2018", 276 pages, Available at: http://www.agri-outlook.org/pages/0,2987,en_36774715_36775671_1_1_1_1_1,00.html.

Pallière, G. and S. Fauveaud, (2009), « Les enjeux des agrocarburants pour le monde paysan au Mali », GERES, AMEDD, ICD, Available at : http://www.geres.eu/images/stories/publis/Enjeux-jatropha-paysans-maliens.

Raizon, D., (2009), « Culture intensive de Jatropha : Manne ou catastrophe? », RFI, In line on 23/06/2009, http://www.rfi.fr/sciencefr/articles/114/article_82102.asp.

Ravallion, M., (1994), « Poverty Comparisons », Harwood academic publishers, 143 pages.

Ravallion, M. and S. Chen (2003). "Measuring Pro-Poor Growth", World Bank, Policy Research Working Paper 2666.

République du Mali, (2008), "Orientations stratégiques et priorités d'investissements agricoles », Conférence de Table Ronde des bailleurs de fonds du Mali, Bamako, http://www.tablerondemali2008.org/html/orientation.pdf.

Renner , R., (2007), "Green Gold in a Shrub: Entrepreneurs target the jatropha plant as the next big biofuel", Green Gold in a Shrub, Scientific American, June. Available at: http://www.scientificamerican.com/article.cfm?id=green-gold-in-a-shrub&page=1.

Rutherford, T., D. Tarr, and O. Shepotylo. (2005). "Poverty Effects of Russia's WTO Accession: Modeling 'Real' Household and Endogenous Productivity Effects." World Bank Policy Research Working Paper 3473, Washington, DC.

Savard, L. (2005). "Poverty and Inequality Analysis within a CGE Framework: A Comparative Analysis of the Representative Agent and Microsimulation Approaches". *Development Policy Review* 23(3): 313–332.

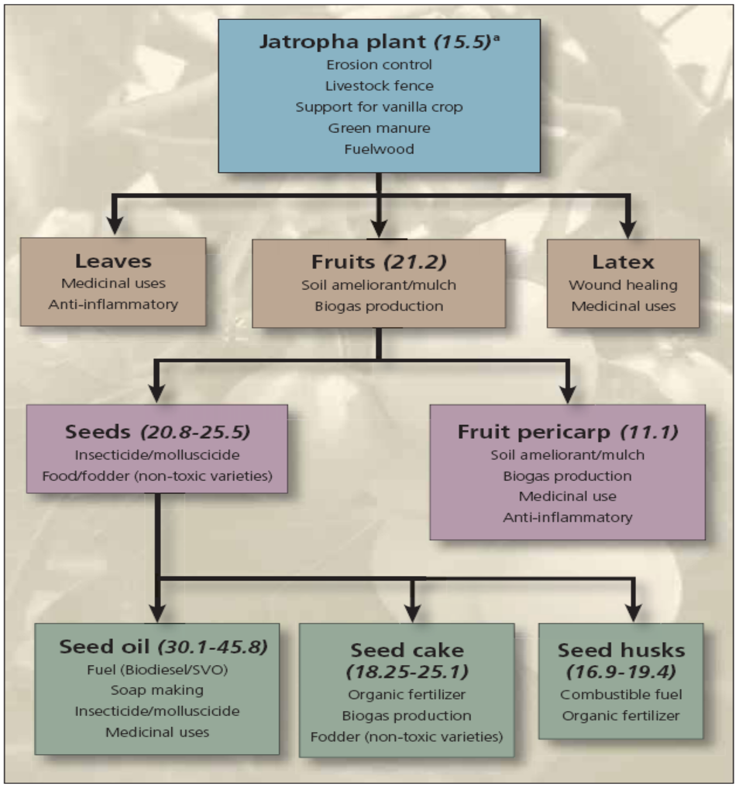
Searchinger, T.; Heimlich, R.; Houghton, R.A.; Dong, F.; Elobeid, A.; Fabiosa, J.; Tokgoz, S.; Hayes, D. and Yu, T. (2008), "Use of U.S. croplands for biofuels increases greenhouse gases through emissions from land use change", *Science* Vol. 319, pp. 1238 – 1240.

Vos, R, De Jong N. (2003) "Trade liberalization and poverty in Ecuador: a CGE macro-microsimulation analysis". *Economic System Research*, 15(2): 211-232.

Word Bank, (2007), "*Mali - Second poverty reduction strategy paper and joint IDA-IMF staff advisory note*", Report # 40724, 241 pages. Avalaible at http://www-wds.worldbank.org/external/default/WDSContentServer/WDSP/IB/2007/10/10/000310607_20071010132454/Rendered/PDF/407240ML0IDA1SecM200710584main.pdf.

8 Appendix

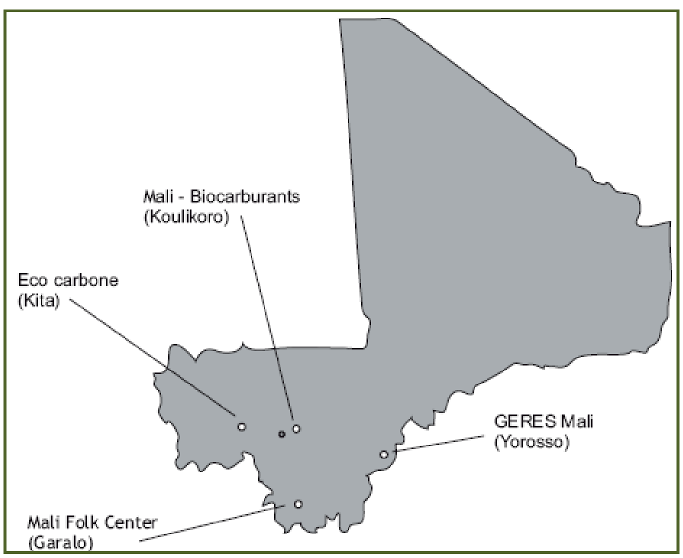
Figure 6: The uses of *Jatropha curcas* and the energy values of its components



Source: Brittaine R. and N. Lutaladio (2010)

[a] Energy values of the components are given in MJ/ kg

Figure 7: Principal jatropha cultivation sites in Mali



Source: Pallière et al. (2009)

The Malian biofuel model

A. Production

A. 1. $Xs_i = \dfrac{Va_i}{v_i}$

A. 2. $CII_i = io_i Xs_i$

A. 3. $Va_m = A_m Ld_m^{\alpha_m} Kdt_m^{1-\alpha_m}$

A. 4. $Va_{snm} = Ld_{snm}$

A. 5. $Ld_m = \dfrac{\alpha_m Pv_m Va_m}{w_m}$

A. 6. $Ld_{snm} = \dfrac{P_{snm} Xs_{snm} - \sum_j Di_{j,snm} Pq_{snm}}{w_{snm}}$

A. 7. $Ld_i = B_i^l \left[\delta_i^l Ldnq_i^{-\rho_i^l} + \left(1-\delta_i^l\right) Ldq_i^{-\rho_i^l} \right]^{-\frac{1}{\rho_i^l}}$

A. 8. $Ldnq_i = \left[\left(\dfrac{\delta_i^l}{1-\delta_i^l} \right) \left(w^1 \big/ w^2 \right) \right]^{\sigma_i^l} Ldq_i$

A. 9. $Di_{m,j} = aij_{m,j} CI_j$

A. 10. $Kdt_{ag} = B_{ag}^K \left[\delta_{ag}^K Kd_{ag}^{-\rho_{ag}^K} + \left(1-\delta_{ag}^K\right) Land_{ag}^{-\rho_{ag}^K} \right]^{-\frac{1}{\rho_{ag}^K}}$

A. 11. $Kd_{ag} = \left[\left(\dfrac{\delta_{ag}^K}{1-\delta_{ag}^K} \right) \left(r_{ag} \big/ Pland \right) \right]^{\sigma_{ag}^K} Land_{ag}$

A. 12. $Kdt_{nag} = Kd_{nag}$

A. 13. $Cii_i = B_i^{ii} \left[\delta_i^{ii} Cie_i^{-\rho_i^{ii}} + \left(1-\delta_i^{ii}\right) Ci_i^{-\rho_i^{ii}} \right]^{-\frac{1}{\rho_i^{ii}}}$

A. 14. $Cie_i = \left[\left(\dfrac{\delta_i^{ie}}{1-\delta_i^{ie}} \right) \left(Pci_i \big/ Pce_i \right) \right]^{\sigma_i^{ii}} Ci_i$

A. 15. $Cie_i = B_i^{ie} \left[\delta_i^{ie} Fuel_i^{-\rho_i^{ie}} + \left(1-\delta_i^{ie}\right) Energ_i^{-\rho_i^{ie}} \right]^{-\frac{1}{\rho_i^{ie}}}$

A. 16. $Fuel_i = \left[\left(\dfrac{\delta_i^{ie}}{1-\delta_i^{ie}} \right) \left(Pq_{ener} \big/ PF \right) \right]^{\sigma_i^{ie}} Energ_i$

A. 17. $Fuel_i = B_i^{fu} \left[\delta_i^{fu} FFuel_i^{-\rho_i^{fu}} + \left(1-\delta_i^{fu}\right) BFuel_i^{-\rho_i^{fu}} \right]^{-\frac{1}{\rho_i^{fu}}}$

A. 18. $FFuel_i = \left[\left(\frac{\delta_i^{fu}}{1-\delta_i^{fu}}\right)\left(Pq_{ffuel} \big/ Pq_{bfuel}\right)\right]^{\sigma_i^{fu}} BFuel_i$

B. Income and savings

B. 1. $$Yh = w^1 Ldhq + w^2 Ldhnq + Tgh + Trh + Div + (\sum_m \lambda^h r_m Kd_m) + \lambda_{rland}^h Pland \sum Land$$

B. 2. $Ydh = Yh - Td - Thr - Thf$

B.3. $Div = tdv(Yf - Tdf - Tfr)$

B.4. $Ye = Thf + Tgf + Trf + \lambda^f (\sum_m r_m Kd_m)$

B.5. $Sh = \psi\left(Ydh - \sum_j Pq_j \gamma_j\right)$

B.6. $Sf = Yf - Div - Tdf - Tfr$

C. Government income

C.1. $Yg = \sum_{im} Tim_{im} + Td + \sum_m Ti_m + Tdf + Trg$

C.2. $Sg = Yg - G - Tgh - Tgr$

C.3. $Ti_{im} = tx_{im}\left(Pl_{im} D_{im}\right) + tx_{im}\left(1 + tm_{im}\right) ePwm_{im} M_{im}$

C.4. $Ti_{nim} = tx_{nim}\left(Pl_{nim} D_{nim}\right)$

C.5. $Tim_{im} = tm_{im} ePwm_{im} M_{im}$

C.6. $Td = tymYm$

C.7. $Tdf = tyfYf$

D. Trade

D.1. $M_{im} = \left[\left(\frac{\delta_{im}^m}{1-\delta_{im}^m}\right)\left(\frac{Pq_{im}}{Pm_{im}}\right)\right]^{\sigma_{im}^m} D_{im}$

D.2. $Q_{im} = B_{im}^m \left[\delta_{im}^m M_{im}^{-\rho_{im}^m} + \left(1-\delta_{im}^m\right) D_{im}^{-\rho_{im}^m}\right]^{-\frac{1}{\rho_{im}^m}}$

D.3. $Xs_e = B_e^e \left[\delta_e^e Ex_e^{\rho_e^e} + (1-\delta_e^e) D_e^{\rho_e^e}\right]^{\frac{1}{\rho_e^e}}$

D.4. $Ex_e = \left[\left(\frac{1-\delta_e^e}{\delta_e^e}\right)\left(\frac{Pe_e}{Pl_e}\right)\right]^{\sigma_e^e} D_e$

D.5. $Q_{nim} = D_{nim}$

D.6. $Xs_{ne} = D_{ne}$

E. Demand

E.1. $Dit_m = \sum_j aij_{m,j} CI_j$

E.2. $Cth = Ydh - Sh$

E.3. $C_i = \gamma_i + \beta_i^c \left[\frac{Cth - \sum_j Pq_j \gamma_j}{Pq_i} \right]$

E.4. $Inv_i = \frac{\mu_i It}{Pq_i}$

E.5. $G = Yg - Sg - Tgh - Tgf - Tgr$

E.6. $Cg_i = \frac{\beta_i^g G}{Pq_i}$

F. Prices

F.1. $Pm_{im} = (1 + tx_{im})(1 + tm_{im}) ePwm_{im}$

F.2. $Pv_i = \frac{P_i Xs_i - \sum_j Di_{j,i} Pq_j}{Va_i}$

F.3. $r_m = \frac{Pv_m Va_m - w_m Ld_m}{Kd_m}$

F.4. $w_i = \frac{w^1 Ldf_i + w^2 Ldi_i}{Ld_i}$

F.5. $Pe_e = Pwe_e e$

F.6. $Pq_{im} = \frac{Pd_{im} D_{im} + Pm_{im} M_{im}}{Q_{im}}$

F.7. $Pq_{nim} = Pd_{nim}$

F.8. $Pd_i = Pl_i (1 + tx_i)$

F.9. $P_e = \frac{Pl_e D_e + Pe_e Ex_e}{Xs_e}$

F.10. $P_{ne} = Pl_{ne}$

F.11. $Pindex = \beta_i^v Pv_i$

F.12. $Pkt_m = \frac{PlandLand_m + r_m Kd_m}{Kdt_m}$

F.13. $Pci_i = \dfrac{Pce_i Cie_i + Pii_i Ci_m}{Cii_i}$

F.14. $Pii_i = \dfrac{\sum_j Pq_j Di_{j,i}}{Ci_i}$

F.15. $Pce_i = \dfrac{Pfuel_i Fuel_i + Pq_{ener} Energ_i}{Cie_i}$

F.16. $Pce_i = \dfrac{Pq_{ffuel} FFuel_i + Pq_{bfuel} BFuel_i}{Cie_i}$

G. Equilibrium conditions

$$Sr = \sum_{im} Pwm_{im} M_{im} + \frac{1}{e}(Tfr + Tgr + Thr + w^1 Ldre+)$$

G.1. $\dfrac{1}{e}(\lambda^r \sum_m r_m Kd_m + \lambda^r_{rland}\ Pland \sum Land)$

$$-\sum_e Pwe_e Ex_e - \frac{1}{e}(Trme + Trg + Trmm)$$

G.2. $Q_{nener} = C_{nener} + Dit_{nener} + Inv_{nener} + Cg_{nener}$

G.3. $Q_{ener} = C_{ener} + Inv_i + Ener_i$

G.4. $Q_{ffue} = C_{ffue} + Inv_{ffue} + FFuel_{ffue}$

G.5. $Q_{bfue} = C_{bfue} + Inv_{bfue} + BFuel_{bfue}$

G.6. $It = Sf + Sg + eSr + Sh$

G.7. $Lsi = \sum_i Ldnq_i$

G.8. $Lsf = \sum_i Ldq_i$

G.9. $Tland = \sum_{ag} Land_{ag}$

H. Endogenous variables

M_{im} : imports

Q_i : composite goods

Xs_i : Sectoral output

Ex_e : exports

Yh : Households' income

CI_i : other intermediate consumption

D_i : domestic demand for local production

Va_i : Value added

$Di_{m,j}$: other intermediate consumption matrix

Dit_m : total intermediate demand

$Ldnq_i$: non qualified labor demand

Ldq_i : qualified labor demand

Ld_i : aggregate labor demand

Kdt_i : Demand for total capital (Land and capital)

$Land_{ag}$: Demand for Land

Cii_i : Total intermediate consumptions

Cie_i : Demand for total energies

$Fuel_i$: Demand for aggregate fuels

$Energ_i$: Demand for other energies

$Ffuel_i$: Demand for fossil fuels

$Bfuel_i$: Demand for biofuels

w^1 : qualified wage

w^2 : non qualified wage

r_m : rental rate of capital

w_i : composite wage

Ydh : household disposable income

Div : Dividend

Yf : Firms' income

Sh : Household savings

Sf : Firm savings

Ti_m : indirect taxes

Tim_{im} : import duties

Td : household income tax

Tdf : firms' income tax

Yg : government income

Sg : government savings

Cth : total household consumption

C_i : household consumption

Inv_i : investment demand

Cg_i : government consumption

G : government expenditure

Pe_e : domestic export prices

Pm_{im} : domestic import prices

Pq_i : composite market price

Pd_i : domestic price of local goods (tax included)

Pl_i : domestic price of local goods (tax excluded)

P_i : producer price

Pv_i : value added price

$Pindex$: GDP deflator

Pkt_m : Price of total capital

Pci_i : Price of total intermediate consumption

Pii_i : Price of other intermediate consumption

Pce_i : Price of total energies

$Pfuel_i$: Price of fuels

$Pland_{ag}$: Price of Land

e : nominal exchange rate

I. Exogenous variables

Lsq : qualified labor supply

Lsi : non qualified labor supply

Kd_m : capital demand

$Ldhq$: qualified labor endowment

$Ldhnq$: non qualified labor endowment

$Ldre$: qualified labor of rest of world

Sr : current account balance or foreign savings

It : total investment

Tgh : government transfers to household

Thr : household transfers to rest of world

Tfr : dividends to rest of world

Thf : household transfers to firms

Tgf : government subsidies to firms

Trh : rest of world transfers to household

Trf : rest of world transfers to firms

Pwm_{im} : world price of imports in foreign currency

Pwe_e : world price of exports in foreign currency

Trg : foreign aid to government

Tgr : government transfers to rest of world

J. Parameters

δ_{im}^{m} : Distributive parameter of CES (Armington import-domestic)

σ_{im}^{m} : Elasticity of substitution for CES (Armington import-domestic)

B_{im}^{m} : scale parameter of CES (Armington import-domestic)

ρ_{im}^{m} : Parameter of CES (Armington import-domestic)

B_e^e : scale parameter of CET (exports-domestic)

δ_e^e : Distributive parameter of CET (exports-domestic)

ρ_e^e : Parameter of CET (exports-domestic)

σ_e^e : Elasticity of transformation of CET (exports-domestic)

δ_{ag}^K : Distributive parameter of CES (total capital)

σ_{ag}^K : Elasticity of substitution for CES (total capital)

B_{ag}^K : scale parameter of CES (total capital)

ρ_{ag}^K : Parameter of CES (total capital)

δ_i^{ii} : Distributive parameter of CES (Total intermediate consumption)

σ_i^{ii} : Elasticity of substitution for CES (Total intermediate consumption)

B_i^{ii} : scale parameter of CES (Total intermediate consumption)

ρ_i^{ii} : Parameter of CES (Total intermediate consumption)

δ_i^{ie} : Distributive parameter of CES (Energy)

σ_i^{ie} : Elasticity of substitution for CES (Energy)

B_i^{ie} : scale parameter of CES (Energy)

ρ_i^{ie} : Parameter of CES (Energy)

δ_i^{fu} : Distributive parameter of CES (Fuels)

σ_i^{fu} : Elasticity of substitution for CES (Fuels)

B_i^{fu} : scale parameter of CES (Fuels)

ρ_i^{fu} : Parameter of CES (Fuels)

δ_i^l : Distributive parameter of CES (labor)

σ_i^l : Elasticity of substitution for CES (labor)

B_i^l : scale parameter of CES (labor)

ρ_i^l : Parameter of CES (labor)

λ^r : rest of world share of capital income

λ^h : Household share of capital income

λ^f : Firm share of capital income

v_i : Leontief share (value added)

io_i : Leontief share (total intermediate consumption)

A_m : scale parameter of Cobb-Douglas (value added)

α_m : Cobb-Douglas parameter (value added

aij_{ij} : input-output shares

tdv : dividend rate for household

ψ : Marginal propensity to save

tx_i : indirect tax rate

tm_{im} : import duties

ty : household income tax rate

tyf : firms' income tax rate

γ_i : committed expenditure

β_i^c : Household marginal rate of consumption

μ_i : investment demand share

β_i^g : Government expenditure share

β_i^v : value added share

Table 10: Annualized per capita poverty line in 2006 (in Fcfa)

		Poverty line
	Mali	157 920
Urban	In jatropha area	156 341
	Outside jatropha area	141 426
Rural	In jatropha area	132 502
	Outside jatropha area	109 343

Source: calculus done by authors from World Bank (2007).
Poverty line based on the basic needs methodology

Table 11: Average per capita expenditure per group (in Fcfa)

Groups	Obs.	Mean	Std. Dev.
MAJU - 1	8 103	237 217.7	281 217.15
MNAJU - 2	41 199	709 975.9	1 188 650.80
MAJR - 3	71 102	182 660.62	160 180.32
MNAJR - 4	21 314	257 064.47	194 386.47
MANJU - 5	61 823	333 356.14	293 279.98
MNANJU - 6	428 191	673 909.07	973 241.45
MANJR - 7	584 520	198 252.09	195 013.78
MNANJR - 8	226 658	305 907.32	1 018 045.6
Mali	1 442 910	377 035.72	742 237.49

Source: Elim, 2006