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Optimization of an oilseed-based biofuels upstream supply chain in West Africa

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Abstract: This study presents an optimization model of the upstream supply chain of an oilseed based-biofuels production system. It has been developed considering West Africa rural context where family farming is mainly practiced. The model has been applied to a theoretical case of study on jatropha seeds supply chain. Four scenarios on farms surface area occupancy and on the transportation means used between farms and feedstock gathering points (GP) have been performed. Considering different farming systems, different seed yield, and different transportation mode, the results show that the most efficient option is the "intercropping" mode with the pre-processing operations located at the farms and with the transportation between farms and GP ensured by carts.

Keywords: Oilseed-based biofuels, post-harvest operations, production and supply chain management, optimization.

1. INTRODUCTION

Biofuels have known in the 2000s a major boom in the world and in Africa (Gatete and Dabat, 2014) due to factors such as the need for the replacement of imported liquid fossil fuels for reducing greenhouse gas emissions, the realization of limited oil stocks, the alternative they represent, etc. (Pradhan and Mbohwa, 2014). This has resulted in many biofuel projects on the African continent. Most of them were based on *Jatropha Curcas* (jatropha) plantation, such as Burkina Faso and Mali which have seen in this oleaginous biofuel production, the opportunity to overcome their dependence on fossil fuels and the opportunity to achieve energy security. Indeed, one of the benefits of *Jatropha Curcas* oil is the possibility of using Straight Vegetable Oil (SVO) for direct use as fuel in diesel engines when the SVO quality standards are met (Blin et al., 2013). Despite the craze and the hype that has been done on jatropha biofuels production in Mali and Burkina Faso, it can be noticed today that these sectors have low profitability and many biofuels projects have even been stopped. According to the final report of the study of the structure, organization and operation of jatropha chains in West Africa (Groupe e-sud, 2014), many projects based on the jatropha seeds transformation into biofuels have stopped their activities due to the lack of cash to finance their activities or have switched to other activities. Furthermore, most projects promoters primarily focused on the development of agriculture practices, varietal improvement, and pest and diseases control of the *Jatropha Curcas*. Meanwhile, the development of seed processing and above all, logistics were rather neglected. Very interesting economic studies have already been carried out on the economic viability of jatropha chains. It is the case of the study (Bouffaron et al., 2012) who developed a decision support tool called "JEALE" to estimate the economic viability of the production of jatropha oil and of the use of the obtain oil in electrical power generators in a rural environment. (Borman et al., 2013) have also developed a model for assessing the economic income from jatropha cultivation in Southern Africa and India. But these studies do not define the modalities which allow the oilseeds to be available in quantity, in quality and on time at seed milling plant (Feedstock Conversion Unit (CU)). Yet, the good management of the feedstock supply chain is inherent in the competitiveness of all kinds of process industries (Papageorgiou, 2009). In this context, the work presented in this paper aims to determine the conditions of profitability of the SVO production systems in West Africa through an integrated approach that takes into account the production and the gathering of the seeds in the farms for the optimal supply of the CU.

2. METHODOLOGY

The model proposed in this paper is a mixed integer linear program (MILP) for strategic and tactical decisions related to the configuration of the upstream supply chain for SVO production systems in West Africa. The decisions concern the

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cultivation and the harvesting of the oilseeds feedstock and the supply logistics (location allocation of the supply units, transportation, and pre-processing operations location). This mathematical model is generic as it can be used to optimize the supply chain of all oleaginous feedstock (perennials or annual) from crops to wild plants. The model structure has been designed so that it can be applied to any other region, regardless of its geographic size.

2.1 The problem and the assumptions

Let us consider a Feedstock Conversion Unit (CU) located in an area where there is a demand for SVO. The CU has an annual minimum processing capacity which enables it to produce the annual demand for SVO. All the feedstock produced and harvested in a farm must pass through a Gathering Point (GP). Indeed, according to our in-field surveys, the GP allow to bring together large amounts of feedstock, and this facilitates the delivery at the CU (mainly the mobilization of labor for loading, unloading and weighing of feedstock). Depending on the choice of the pre-processing (dehulling, cleaning, drying …) location, the demand for feedstock of the CU can represent the non-pretreated raw feedstock or the pretreated raw feedstock. There are 3 possible locations for the preprocessing: "in farms", "at the GP" and "at the CU". A finite number of farms are scattered throughout the region of interest. We assume that these farms are able to produce the raw feedstock demand of the CU. Due to geographical constraints, several GP sites are selected in advance. The transports of feedstock between the GP are not possible. The CU must be supplied with the demand for feedstock so as to minimize the supply total costs and satisfy a number of constraints.

2.2 Mathematical formulation

The mathematical formulation of the problem consists of an objective function to minimize (1) and a set of constraints (8) to (37). The objective function is composed of the costs induced between the production of the feedstock in farms and the entrance of the CU. These costs are: feedstock cultivation costs (2), feedstock harvesting costs (3), feedstock transportation costs from the farms to the GP (4), and feedstock transportation costs from the GP to the CU (5). For the sake of clarity, the elements that compose the mathematical model are stated and described below.

Sets: Farms are represented by the index b, GP by the index k, technical route of cultivation (TRC) by the index j, CU by the index h, transportation means by the index m, time periods by the index t and pre-processing location sites by the index p.

Parameters: QTh is the CU demand for non-pretreated raw feedstock if feedstock loses is considered. δ is the remaining fraction of feedstock after the pre-processing. τ is Tortuosity factor. S_b is the total available surface area of a farm. To_b^t is the occupancy rates of the farm surface area by the energy crop at period t. $Rend_j^t$ is the seed yield of a TRC j at period t. Cc_j^t is the unitary costs of cultivation with the TRC j at period t. Cr_j^t is the unitary costs of harvesting with the TRC j at period t. $a_{b,k}$ define the potential allocation of a farm b to a GP k. $d_{b,k}$ is the distance between a farm b and a GP k. $d_{k,h}$ is the distance between a GP and the CU. d_m is the maximum travel distance per day for a transportation mean m. $x_{b,m}$ is a binary parameter that define if transportation mean m is available in a farm b. Q_p is the quantity of feedstock expected at the CU depending on the location of the pre-processing. QPR_p is the quantity of feedstock expected at all the chosen GP depending on the location of the pre-processing p. Dem_k is the minimum quantity of feedstock required in a GP. Cap_k is the maximum capacity of a GP. $C_{b,k}$ is the transportation cost per quantity unit of feedstock between a farm and a GP. $C_{k,h}$ is the transportation cost per quantity unit of feedstock between a GP and the CU. C_m is the unitary transportation cost of the mean of transportation m and C_{truck} is the unitary transportation cost of the truck. Pr_m and P_{truck} are the purchasing prices of the mean of transportation m and of the truck.

Variables description: $S_{b,j}^t$ is the cultivated surface area of a farm b if the TRC j is chosen at period t . y^t is a binary variable that decide the choice of the period t. y_b is a binary variable that decide the choice of a farm b. y_j is a binary variable that decide the choice of TRC j. $y_{b,j}^t$ is a binary variable that decide the simultaneous choice of TRC j on a farm b at period t. y_k is a binary variable that decide the choice of a GP k. y_p is a binary variable that decide the location of the pre-processing. $Q_{b,k,p}^t$ is the quantity of feedstock to be transported from a farm b to a GP k at period t if the location of the pre-processing p is chosen. $Q_{k,h,p}^t$ is the quantity of feedstock to be transported from a GP k to the CU at period t if the location of the pre-processing p is chosen. $Q_{b,p}^t$ is the quantity of feedstock available for the transportation in a farm b depending on the location of the pre-processing p at period t.

Equations

$$Min\ (CC + HC + TC_{bk} + TC_{kh}) \quad (1)$$

$$S_{b,j}^t \geq 0\ \forall\ b, j, t$$

$$Q_{b,k,p}^t \geq 0\ \forall\ b, k, t, p$$

$$Q_{k,h,p}^t \geq 0\ \forall\ k, h, t, p$$

$$y_{b,j}^t, y_{b,j}, y^t \in \{0,1\}\ \forall\ b, j, t$$

$$y_k, y^t, y_p \in \{0,1\}\ \forall\ k, t, p$$

$$CC = \sum_{b,j,t} Cc_j^t . S_{b,j}^t \quad (2)$$

$$HC = \sum_{b,j,t} Cc_j^t . S_{b,j}^t \quad (3)$$

$$TC_{bk} = \sum_{b,k,t,p} (C_{b,k} . Q_{b,k,p}^t + (Q_{b,k,p}^t / \sum_{b,j,t} Q_m . x_{b.m}). (\sum_m Pr_m . x_{b,m})) \quad (4)$$

$$TC_{kh} = \sum_{k,h,t,p} (C_{k,h} . Q_{k,h,p}^t + (Q_{k,h,p}^t / Q_{truck}). Pr_{truck})) \quad (5)$$

$$C_{b,k} = 2. d_{b,k} . \tau . C_m . x_{b,m}\ \forall\ b, k, m \quad (6)$$

$$C_{k,h} = 2. d_{k,h} . \tau . C_{truck}\ \forall\ k, h \quad (7)$$

$$a_{bk} = \begin{cases} 1\ if\ d_{bk} \leq d_m . x_{b,m} \\ 0\ if\ no \end{cases} \forall\ b, k, m \quad (8)$$

$$\sum_{b,t,j} S_{b,j}^t . Rend_j^t \geq QTh \quad (9)$$

$$S_{b,j}^t \leq S_b . To_b^t . y_{b,j}^t\ \forall\ b, j, t \quad (10)$$

$$\sum_j S_{b,j}^t \leq S_b . To_b^t\ \forall\ b, t \quad (11)$$

$$\sum_t S_{bj}^t \leq \sum_t S_b . To_b^t . y_b\ \forall\ b, j \quad (12)$$

$$S_{b,j}^t \leq y_{b,j}^t\ \forall\ b, j, t \quad (13)$$

$$\sum_b y_b \geq 1 \quad (14)$$

$\sum_t y^t \geq 1$ (14)
$\sum_j y_j \geq 1$ (16)
$y_{b,j}^t \leq y_j \; \forall\, b, j, t$ (17)
$y_{b,j}^t \leq y^t \; \forall\, b, j, t$ (18)
$y_{b,j}^t \leq y_b \; \forall\, b, j, t$ (19)
$Q_p = QTh \Rightarrow p = \text{"at the CU"} \; \forall\, p$ (20)
$Q_p = QTh.\delta \Rightarrow p \neq \text{"at the CU"} \; \forall\, p$ (21)
$QPR_p = QTh \Rightarrow p = \text{"in farms"} \; \forall\, p$ (22)
$QPR_p = QTh.\delta \Rightarrow p \neq \text{"in farms"} \; \forall\, p$ (23)
$Q_{b,p}^t = \sum_j S_{b,j}^t . Rend_j^t . \delta \Rightarrow p = \text{" in farms"} \; \forall\, b, t, p$ (24)
$Q_{b,p}^t = \sum_j S_{b,j}^t . Rend_j^t \Rightarrow p \neq \text{"in farms"} \; \forall\, b, t, p$ (25)
$\sum_k Q_{b,k,p}^t \leq Q_{b,p}^t . y_p \; \forall\, b, t, p$ (26)
$Q_{b,k,,p}^t \leq Q_{b,p}^t . a_{b,k} \; \forall\, b, k, t, p$ (27)
$\sum_{b,k,t,p} Q_{b,k,p}^t \leq \sum_{b,t,p} Q_{b,p}^t$ (28)
$Q_{b,k,p}^t = \sum_j S_b . TO_b^t . Rend_j^t . \delta . y_p \Rightarrow p = \text{" in farms"} \; \forall\, b, t, p$ (29)
$Q_{b,k,p}^t = \sum_j S_b . TO_b^t . Rend_j^t . y_p \Rightarrow p \neq \text{" in farms"} \; \forall\, b, t, p$ (30)
$\sum_{b,k,t} Q_{b,k,p}^t \geq QPR_p . y_p \; \forall\, p$ (31)
$\sum_{b,t,p} Q_{b,k,p}^t \leq Cap_k . y_k \; \forall\, k$ (32)
$\sum_{b,t,p} Q_{b,k,p}^t \geq Dem_k . y_k \; \forall\, k$ (33)
$Q_{k,h,p}^t = \sum_b Q_{b,k,p}^t \; \forall\, k, h, t, p$ (34)
$\sum_{k,h,t} Q_{b,k,p}^t \geq Q_p . y_p \; \forall\, p$ (35)
$\sum_k y_k \geq 1$ (36)
$\sum_p y_p = 1$ (37)

Equation (6) calculates the transportation cost per feedstock quantity unit between a farm and a GP and equation (7) the transportation cost per feedstock quantity unit between a GP and the CU. Equation (9) ensures that the quantity of raw feedstock to produce on all the selected farms must satisfy the demand of the CU. Equations (10) to (13) ensure that the surface area mobilized by each chosen farm *b* cultivated with the selected TRC *j* at each period *t* to produce the demand for CU will not exceed the available surface area of each farm at each period. Equation (14) states that several farms can be chosen. Equation (15) states that more than one period can be chosen. Equation (16) states that several TRC can be selected. Equations (17) to (19) allow the simultaneous choice of a farm *b*, of a TRC *j*, and of a period *t*. Equations (20) and (21) calculate the quantity of feedstock required at the CU depending on the location of the pre-processing. Equations (22) and (23) calculate the total quantity of feedstock to gather in all the GP depending on the location of the pre-processing and depending on the period in order to meet the demand of CU. Equations (24) and (25) calculate the quantities of feedstock available in each farm for the transportation, depending on the location of pre-processing. Equations (26) to (30) ensure that the quantities of feedstock transported from the chosen farms to the chosen GP at each period depending on the choice of the pre-processing location, must not exceed the quantities of feedstock available in the farms for the transportation at each period depending on the choice of location of pre-processing. Equation (31) ensures that the sum of the quantities of feedstock transported between the chosen farms and the chosen GP have to satisfy the minimum quantity of feedstock expected in all the chosen GP depending on the location of the pre-processing in order to satisfy the demand of the CU. Equation (32) ensures that the maximum capacity of a selected GP must not be exceeded. Equation (33) ensures that the minimum demand of each selected GP have to be satisfied. Equation (34) calculates the quantity of feedstock to transport between each selected GP and the CU. Equation (35) ensures that the sum of the quantities of feedstock transported between the chosen GP and the CU, have to satisfy the demand of the CU depending on the location of the pre-processing. Equation (36) ensures that several GP can be chosen. Equation (37) ensures that only one location of the pre-processing can be chosen.

3. CASE OF STUDY

The model has been implemented on a theoretical case study of jatropha seeds supply chain. The case study was constructed on the basis of common practices in Burkina Faso and Mali. Because of the lack of reliable data on some parameters related to the farmers' choices and to the energetic crop chosen as feedstock, scenarios are performed. Data and assumptions are retrieved from peer-reviewed literature and expert opinions. Therefore, the costs calculated reflect the real costs that can be observed in Burkina Faso and Mali.

We assume a CU in a region of 4200 km^2 with suitable soil and climate conditions for jatropha cultivation. The raw feedstock demand of the CU is 400 tons/year. The feedstock losses from the harvesting to the entrance of the CU are set to 5 % of this demand. Dry jatropha fruit contains about 35% – 40% shell and 60% - 65% seed by weight (Vyas and Singh, 2007). On this basis, the demand for pre-treated feedstock of the CU is 262.5 tons/year if we consider that the remaining fraction of feedstock after the pre-processing (removing of shells) is 62.5 %. In this region, 122 farms have been identified for jatropha cultivation. 26 GP have also been identified. The minimum demand of each GP is 10 tons and their maximum capacity is unlimited. The geographical coordinates of farms and their surface, the geographical coordinates of the GP and of the CU have been randomized once and the resulting supply network has been used for all the study. The surfaces value range is 1.5 ha to 12 ha in accordance with the surfaces of small farmers' farms in West Africa. All distances are Euclidean distances to which a tortuosity factor has been applied. With no knowledge on the road network of the study area, the value of the tortuosity factor can only be estimated. For our case, it value has been set to 1.5. The cultivation and harvesting activities of jatropha take place in the rainy season. So for our case we have one time period for cultivation and harvesting. The occupancy rate of each farm by the energetic crop is normally chosen by farmers who are the only empowered to decide the mode of exploitation of their farm surface area. This occupancy rate reflects the mode of exploitation of the farms surface area ("sole crop", "intercropping", "hedgerows", etc.). For example, for 1 hectare, if each jatropha plant is planted with a gap of 2m × 2m, the occupancy rate of energetic crops will be about 10 % if the mode "hedgerows" is selected. This rate will be about 50 % if the mode "intercropping" is selected with a gap of 8m × 2m between each jatropha plant. The costs of cultivation and of harvesting per hectare are estimated based on their corresponding labor costs and taking into account the costs of agricultural inputs. A man-day is assumed to equate 8 hours and the daily pay minimum for farm workers is 1363.91 XOF/day (MBF, 2007). XOF is West African CFA francs. Based on the work and the observations done on jatropha plantations in Mali by (Dembélé and Tréboux, 2015; Tréboux and Desquilbet, 2013) since 2008, we assume 3 technical routes of cultivation (TRC) whose attributes are mentioned in table 1. The TRC1 concerns the breeding of jatropha plants in nurseries and their planting. The TRC2 includes the activities of TRC1 and the care of the plants (pruning, weeding, etc.). The TRC3 includes the activities of the TRC2 and the fertilizing. The seed yields and the labor are estimated for trees planted in 2010 and fruits harvested in 2014 (four years after planting) and they correspond to a plants density of 1250 plants/ha (gap of 4m × 2m between each plant).The seed yield is assumed to be constant after the first year of harvesting i.e. after 4 years of cultivation. The annualized fertiliser cost is took account in the unitary cultivation cost of the TRC3. The interest rate is 5% over 5 years. The fertilizer total demand for four years estimated by (Jongh and van der Putten, 2010) and their prices given by (RECA Niger, 2011) are 229 kg/ha 783 XOF/kg for N, 71 kg/ha and 1859 XOF/kg for P_2O_5, 336kg/ha and 966 XOF/kg for K_2O. The harvesting labor costs are calculated based on a fruits picking rate of 2.3kg/hour (Allard, 2010). Carts pulled by donkeys and motors tricycles are considered for the transportation between the farms and the GP. Trucks older than 15 years are considered for the transportation between the GP and the CU. The unitary cost of transportation for carts and tricycles are estimated on the basis of the minimum wage for the driver, of the maximum load per travel, of the velocity of each mean and of the fuel consumption for the tricycle. For carts, this cost is 136 XOF/ton.km. Its maximum load is about 0.5 tons (Lhoste et al., 2010) and the maximum traveling distance covered in a day is 20 km when considering a velocity of 5km/h (Lhoste et al., 2010) and a work day of 8 hours. For tricycles, this cost is 27 XOF/ton.km. Its maximum load is 1.1 ton and its fuel consumption is 3.5l/100km (Füllemann, 2015). The maximum distance covered in a day is 160 km when considering a velocity of 40 km/h and a work day of 8 hours. For truck, this cost is 52 XOF/ton.km for roads with no bitumen (AMASSA AFRIQUE VERTE MALI, 2009). Its maximum load is about 10 tons. The fixed cost for each mean is presented in table 2.

Four scenarios are performed. In scenario 1 (Sc1), all the farms occupancy rate is set to 100% and the cart is used for transportation between the farms and the GP. In scenario 2 (Sc2), all the farms occupancy rate is set to 100% and the tricycle is used for transportation between the farms and the GP. In scenario 3 (Sc3), all the farms occupancy rate is set to 50% and the cart is used for transportation between the farms and the GP. In scenario 4 (Sc4), all the farms occupancy rate is set to 50% and the tricycle is used for transportation between the farms and the GP. The occupancy rate 100 % is assimilated to the "sole crop" and the occupancy rate 50% is assimilated to the “intercropping".

Table 1. Attributes of the technical routes of cultivation

	TRC1	TRC2	TRC3
Seed yield (ton/ha)	0.475	0.665	1.25
Cultivation labor (man-day/ ha)	34	139	154
Harvesting labor (man-day / ha)	26	36	68
Cultivation costs (XOF/ha)	46032	189243	356572
Harvesting costs (XOF/ha)	35210	49293	92657

Table 2. Attributes of transportation means

	Tricycle	Cart	Truck
Interest rate	0,05	0,05	0,05
Life time (year)	5	5	10
Fixed cost (XOF)	230975	30027	518018
Unitary cost (XOF/ton.km)	27	136	52

4. RESULTS AND DISCUSSION

The model is implemented and solved in the optimization software Xpress IVE 7.9. The experiments were performed on an Intel Core i7- 5500U CPU 2.4 GHz with 8 GB RAM on a 64-bit platform. The solution was obtained in less than 5 seconds using the Branch and Bound method. The model determines the surface area and the TRC for each farm, the number and the allocation of the farms and of the GP, the quantity of harvested feedstock to transport, the location of the pre-processing. Later in the paper, the distribution of the seeds cost price at the CU gate are firstly presented and discussed. Then, the results of the pre-processing location are presented and discussed. And to end, the results of the implementation are discussed according to the farms occupancy rate and according to the means of transportation.

Fig.1. presents the distribution of the seeds cost price at the CU gate in the first year of harvesting i.e. with cultivation cost. Fig.2. presents the distribution of the seeds cost price at the CU gate in the years after this first year of harvesting i.e. without cultivation cost. Each component of this cost price represents the cost per kg of treated feedstock. The CU gate cost price represents the sum of the costs induced to cultivate, harvest, and transport the feedstock to the CU. The farm gate cost price represents the sum of the cultivation and harvesting costs. These results on Fig.1. and Fig.2. show that in the first year of harvesting, the lowest farm gate cost price (193 XOF/kg) has been found in Sc2 while the lowest cost price at the GP (277 XOF/kg) and the lowest CU gate cost price (338 XOF/kg) have been found in Sc1. Meanwhile, after the first year of harvesting the lowest farm gate cost price (28 XOF/kg), the lowest cost price at the GP (104 XOF/kg) and the lowest CU gate cost price (164 XOF/kg) have been found in Sc3. It means that the most efficient option in this case study is the "intercropping" mode with the transportation between farms and GP ensured by the carts. It can be also

noticed that after the first year of harvesting, the transportation costs account for over 60% (90% for scenario 4) of the feedstock cost price at the CU gate.

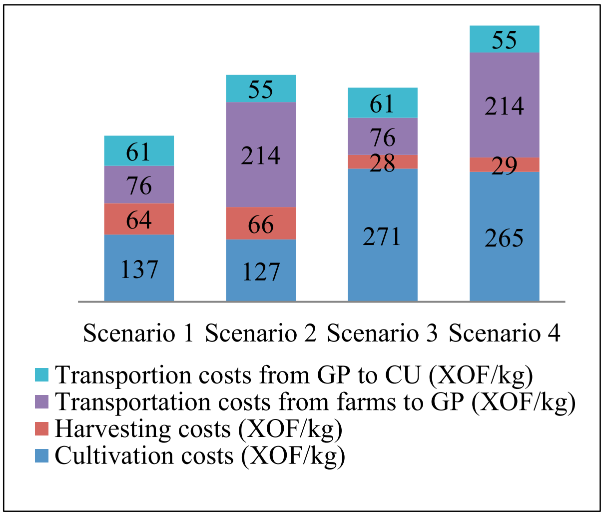

Fig. 1. CU gate cost price distribution for the first year of harvesting

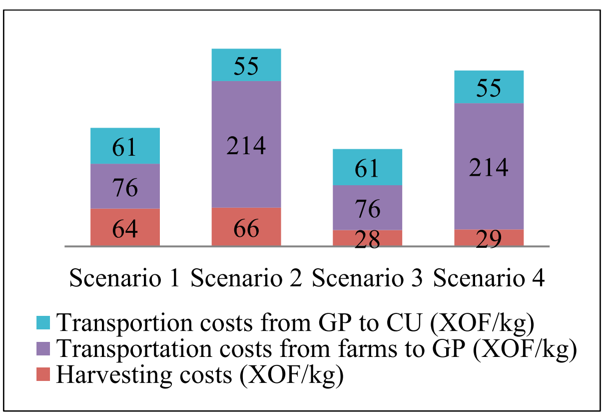

Fig. 2. CU gate cost price distribution after the first year of harvesting

Concerning the pre-processing location, the location "in the farms" is always chosen for all the scenarios. This makes sense if the valorization of the coproducts is not envisaged. There is indeed about less than 38% of material to transport from the farms to the CU when the pre-processing location "in the farms" is chosen.

Regarding the farms occupancy rate, the results show that the total cultivated surface of all the farms vary between 379 ha and 396 ha for the scenarios with the "intercropping" mode (Sc3 and Sc4) and between 770 ha and 797 ha for the scenarios with the "sole crop" mode (Sc1 and Sc2). It can also be seen from the results that the TRC1 is chosen for 90% of the farms in the scenarios with the "intercropping" mode and the TRC3 is chosen for 90% of the farms in the scenarios with the "sole crop" mode (see Table 3.). This can be explained by the fact that the model chose the TRC that generate the highest crop yield when the available surface area is limited. It means that the "intercropping" mode leads to the use of less surface area compared to the mode "sole crops" whatever the means of transportation. However, this "intercropping" mode requires the use of TRC which induce high crop yields. Moreover, this TRC which induce high crop yields is those which has the highest cultivation cost. It is the reason why the scenarios with the "intercropping" mode generate a high farm gate cost (around 300 XOF/kg. See Fig. 1).

Table 3. Number of farms and number of GP

	Sc1	Sc2	Sc3	Sc4
Number of farms	106 TRC1	111 TRC1	17 TRC1	24 TRC1
	18 TRC3	11 TRC3	99 TRC3	96 TRC3
Number of GP	20	3	19	4

The results analyzing according to the means of transportation show that less than 20% of the GP are opened for the scenarios with the tricycle (Sc2 and Sc4) and more than 70% of the GP are opened for the scenarios with the cart (Sc1 and Sc3) (see table 3.). This can be explained by the short travel distance per day of the cart (20km) compared to the travel distance per day of the tricycle (160 km). The transportation cost with the tricycle (214 XOF/kg for Sc2 and Sc4) is 3 times higher than the transportation cost with the carts (76 XOF/kg for scenarios 1 and 3). This can be explained by the fixed costs of the tricycle that are 7.7 times higher than the fixed costs of the cart (see table 2). The number of trip to transport all of the harvested feedstock is however 3 times higher for the tricycle. This number is 238 trips for the tricycle and 657 trips for the cart. As concerns the configurations of the supply network, they are similar for the scenarios with the cart (Sc1 and Sc3). They are also similar for the scenarios with the tricycle (Sc2 and Sc4). The configuration of the supply network is thus defined in this case study by the means of transportation. (See Fig. 3 and Fig. 4. The red arrows represent the transport from the farms to the GP; the blue arrows the transport from the GP to the CU; the green boxes the farms and the blue boxes the GP).

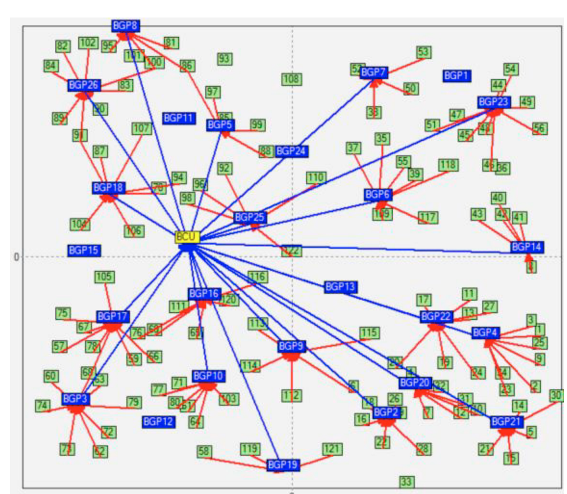

Fig. 3. The supply network in scenario 3

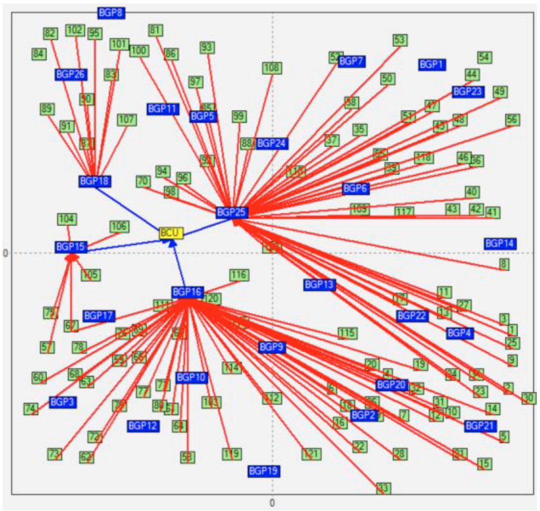

Fig. 4. The supply network in scenario 4

5. CONCLUSION

In this paper, a mathematical model for strategic and tactical decisions in a biofuel based-oilseed upstream supply chain has been described. The model has been implemented on a theoretical case study of jatropha seeds supply chain in the context of Burkina and Mali. The results of the implementation show that after the first year of harvesting, the transportation cost represents more than 60% of the seeds cost price at the CU gate. Therefore, jatropha seeds supply chain management cannot be neglected during the implementation of jatropha projects. The results also show that it is possible to produce jatropha seeds with the “intercropping” mode. The farmers thus didn’t have to allocate all the surface area of their farms to the biofuels feedstock cultivation. This result is important in countries such as Burkina Faso and Mali where agriculture is mainly subsistence farming based on family farming. However, the "intercropping” mode require technical routes of cultivation with high crop yields. These technical routes of cultivation with high crop yields are those with the highest cultivation costs. So, there is a need in performing researches in order to reduce the costs of these TRC. In addition, the lowest cost prices at the GP and at the CU gate found in this paper are higher than the current purchase prices of jatropha seeds at the same locations in Burkina Faso. The purchase prices in Burkina Faso are 85XOF/kg at the GP and 100 XOF/kg at the CU gate. It is the reason why the study of the reverse supply chain, integrating the recovery (energetics or as fertilizers) of residues from the seeds pre-processing and pressing, will be the subject of our future work. The aim is to examine the benefits that the reverse supply chain might have on the oilseed feedstock cost price.

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