PERSPECTIVES OF INCREASING BIODIESEL PRODUCTION THROUGH INTRODUCTION OF *JATROPHA CURCAS* L. INTO SUBSISTENCE FARMING SYSTEMS: EXPERIENCE FROM NORTH SUMATRA, INDONESIA

Vladimir Verner, David Herak, Satya Simanjuntak, Ludvik Andert
Czech University of Life Sciences Prague
vernerv@its.czu.cz

Abstract: *Jatropha curcas* L. represents a promising oil-bearing crop particularly used for biodiesel production. The paper presents the economic analysis of *Jatropha curcas* L. planting among subsistence small-holders. The results are discussed with oil palm agribusiness and socioeconomic situation of target area. Environmental aspects are taken into consideration as well. Oil palm requires fertile soil, which together with the increasing demand of biofuels, strongly contributes to clash between food and energy crops and/or supports continuous deforestation while *Jatropha curcas* L. can be planted at a marginal, or otherwise not-used, land, since its requirements are lower comparing to oil palm, e.g., in the terms of soil quality, water supplies or skilled labour inputs. However, low purchasing price of the final product, seeds, makes *Jatropha curcas* L. less economically promising business for small-holders due to its long payback period and low rates of return. Simple cost-benefit analysis (CBA) is carried out in order to analyze the economic potential of planting *Jatropha curcas* L. under the specific natural and socioeconomic conditions of North Sumatra province, Indonesia. Different scenarios are proposed and the role of the government, small-holders and private capital are discussed. Special attention is focused on support to initial costs, which are the most important for maintaining the plantation, by development agencies or microfinance institutions, and, purchasing price increasing through the both development of market-chain as well as through contracting the farmers by state and/or private companies.

Keywords: *Jatropha curcas* L., oil palm, vertical integration, cost-benefit analysis, farming systems, contract farming, Indonesia.

Introduction

During the last decade *Jatropha curcas* L. (JCL) has became a highly promoted promising oil-bearing crop particularly used for biodiesel production [1]. Similarly to oil palm, JCL produces non-edible oil that is of high quality standards and which can be easily converted into liquid biofuels ready to meet the technical requirements of the European Union or the United States of America [2; 3]. Nevertheless, instead of the above mentioned utilization, there are several categories of JCL use described in the literature, such as medicinal purposes [4 – 6], oil for soap production [1; 7; 8], green manure, composting or vermiculture [9 – 11], soil erosion control [7], sericulture [7], fodder [7], poverty alleviation through employment generation [12] or farm protection as a hedge and biocide [7]. Beside the above mentioned uses it is necessary to mention that in comparison to other oil-bearing crops, particularly oil palm, high resistance and adaptability to local environment has to be also considered as a very important factor making JCL worth of planting in tropical countries [5].

Indonesia represents one of the two leading producers of palm oil in the world [13], which has been planted particularly on the large plantations. Especially high financial inputs keep the small-holders far from potential benefits from this business. In this case, JCL, the ecological and financial requirements of which are more suitable to meet the farmers' capacities, seems to be a suitable solution how to reduce poverty, solve environmental issues (soil erosion, unused land) and to produce a product with high market potential. Until now, JCL is cultivated particularly on Java and Sulawesi, while other potential areas are under research [14]. To extend the areas under JCL cultivation is supported by the Indonesian government [15].

Thus, the objective of the paper is to provide an economic analysis of growing of JCL under the specific natural and socioeconomic conditions of North Tapanuli district and judge whether it could serve as a potential area for JCL cultivation among small-holders. The study focuses on answering the following questions: (1) What are the most important costs the farmer has to invest in JCL planting? (2) What is the cost-benefit ratio under the present purchasing price level? (3) Which extension approaches can increase and/or sustain the efficiency of JCL cultivation in the target area?

Materials and methods

Study site description

Research was conducted in the North Tapanuli district, which is situated in the central part of North Sumatra province some six hours (or 232 km) south off Medan. The total area covers 3,812 km^2 and the alleviation ranges from 300 to 1,800 m a.s.l. [16]. Average temperature varies from 23.7 ºC during winter to 32.2 ºC in summer. Correspondingly, average rainfall fluctuates from 95 mm during the summer dry season to 297 mm in the winter time of rains. Humidity very rarely drops bellow 80 % [16; 17]. Such climatic conditions perfectly suit to ecological requirements of JCL [5].

The population density reaches 70 people per square km, while majority of the population live in the rural areas. The average farm size has not changed much since mid-1990s when it represents 0.86 hectares per household [18]. Local farming systems are oriented on annual crops plating, particularly rice, cassava, maize or vegetable, but due to lack of water and poor soils, mixture with perennial crops and livestock (pigs, buffaloes and poultry) were observed as well. Additionally, in order to support the value and market-chain development as well as to alleviate poverty in the target area, coffee, rubber or cinnamon, followed by pineapple and tobacco have become very important cash-crops since mid-2000s [19; 20].

Data collection and processing

The data were collected during summer months of the years of 2007 and 2008 among randomly selected farmers in North Tapanuli district. Via face-to-face discussions and transect walks, the data on the farming system economics, market access, future expectation and most pressing economic and environmental problems were gathered. Local administration representatives provide us with the development plans, socioeconomic indicators and extension practice. Finally, major companies involved in renewable energy provide us with the details and constraints of JCL cultivation among small-holders, price fluctuation and possible value-chain development. The collected data were entered into MS Office Excel and processed via simple cost-benefit analysis [21; 22].

Results and discussion

Costs

Establishing the plantation represents the most significant financial burden a farmer has to face in the case he/she would decide to become a JCL producer. Lack of cash has been identified as one the most serious constraints of farming system development in the target area, which is in correspondence with other studies [19]. The advantage is that in comparison to the land suitable for other cash-crops, land for JCL can be purchased at a significantly lower price, usually for USD 1.09 per one hectare (see Table 1). From the table it is obvious that majority of the costs go to seedling purchase and labour force, 38.1 % and 39.4 % respectively, which is similar to other studies from Asian countries [23]. The total sum of costs is equal to 353 USD, which is too much for subsistence farmers to establish such a plantation without any external financial support. Thus, the role of the government, banking systems or microfinance activities is crucial.

Table 1

Costs of establishing plantation of JCL

Cost	USD	%
Land	1.09	0.31
Seedlings	134.67	38.13
Labor	139.13	39.40
Site preparation	30.43	8.62
Planting	6.52	1.85
Maintenance	73.91	20.93
Harvesting	28.26	8.00
Material	66.30	18.78
Tools/Equipment	11.96	3.39
Total costs	353.15	100.00

The costs of labour are equal to the average daily wage for hired labour that was observed in the target area, e.g., USD 2.2 per day. The labour requirements in man-days were discussed with farmers as well as with local key informants and were estimated as follows: site preparation 14, planting 3, maintenance 34 and harvesting 13. The purchasing price of seedlings depends on the demanded amount at the local market and for the purposes of the study, 0.11 USD per one seedling was considered. The number of seedlings was estimated on 1,239 (1,039 per hectare according to common plantation design, 200 as a reserve). The assumed extensive system of JCL planting does not require a lot of material and only simple hand-tools. For other years, the following costs are considered (in USD): labour 102.2, tools 12.0 and material 66.3, totally USD 180.5. Average overhead costs reach USD 87 per hectare in the first year of plantation and USD 10.9 per hectare since the second year onwards.

Benefits

Benefits are represented by revenues from selling seeds to oil producing companies. Selling of oil will be more profitable comparing to selling only seeds, but the farmers in the target area are not able to process seeds. Thus, any development efforts oriented on vertical integration of JCL cultivation among rural households would be considered as a significant intervention. The farmers who dispose sufficient cash can invest into a simple press machine and increase so their final benefits through higher added value (e.g. JCL cakes). The maximum yield a farmer can reach in the specific conditions of North Tapanuli is 5,000 kg of seed per hectare, which was observed also in other research areas in Indonesia [24]. Thus, in the case of selling only seeds, the total revenues per hectare will reach USD 271.7 per hectare. Generally, despite of almost equal annual cost per hectare, the total revenues from one hectare of JCL are at the level between 40 – 45 % in comparison to palm oil, particularly due to lower yield [14; 25; 26].

Furthermore, JCL biomass can be sold for USD 0.27 per kilogram, but the real revenue from this source is still hard to define as it is highly dependent on the pharmaceutical company, which might be interested only in specific parts, with a specific quality. Theoretically, if counted with the harvest index of seeds of 0.35 and the yield of 5,000 kg of seeds, then the total biomass weight is 14.29 tons. But, of course, only a small part of the biomass could be used in order to maintain the plantation fertility. That is why the sale of biomass is not included in our calculations.

Cost-benefit analysis

Table 2 sums the most potential benefits and the most relevant costs that a small-holder from North Tapanuli has to take into consideration if he/she wants to run JCL plantation. Generally, as it was already mentioned, the first years require huge financial inputs from the perspective of the small-holder household economy level. In this case, low adoption rate of JCL among local household could be expected.

Table 2

Costs of establishing plantation of *Jatropha curcas* L. in study area

Year of plantation	MU	1	2	3	4	5 onwards
Yield	$kg \cdot ha^{-1}$	1,000	2,000	3,000	4,000	5,000
Seed price	$USD \cdot kg^{-1}$	0.05	0.05	0.05	0.05	0.05
Benefits	USD	54.35	108.70	163.04	217.39	271.74
Costs	USD	440.11	191.30	191.30	191.30	191.30
Balance	USD	-385.76	-82.61	-28.26	26.09	80.43
Benefit-cost ratio	–	0.12	0.57	0.85	1.14	1.42

Table 3 shows the results of the benefit-cost analysis. Based on similar studies [22], two discount rates were applied, 10 % and 20 %, in order to approximate the social cost of capital and market borrowing rate, respectively, and the period of plantation was set on 20 years. In the case of lower rate, the net present value (NPV) reaches the positive value equal to USD 7.44 and the benefit-cost ratio (BCR) 1.004, comparing to the NPV equals to USD -199.1 and BCR 0.825 for a higher rate. Correspondingly, the internal rate of return (IRR) is equal to 10.36 %.

Table 3

Economic evaluation of *Jatropha curcas* L. cultivation in study area

Year (t)	Costs (C)	Benefits (B)	Discount factor (q) i = 10 %			Discount factor (q) i = 20 %		
			C_t/q^t	B_t/q^t	NPV	C_t/q^t	B_t/q^t	NPV
1	440.1	54.4	400.1	49.4	-350.7	366.8	45.3	-321.5
2	191.3	108.7	158.1	89.8	-68.3	132.9	75.5	-57.4
3	191.3	163.0	143.7	122.5	-21.2	110.7	94.4	-16.4
4	191.3	217.4	130.7	148.5	17.8	92.3	104.8	12.6
5	191.3	271.7	118.8	168.7	49.9	76.9	109.2	32.3
6	191.3	271.7	108.0	153.4	45.4	64.1	91.0	26.9
7	191.3	271.7	98.2	139.5	41.3	53.4	75.8	22.4
8	191.3	271.7	89.2	126.8	37.5	44.5	63.2	18.7
9	191.3	271.7	81.1	115.2	34.1	37.1	52.7	15.6
10	191.3	271.7	73.8	104.8	31.0	30.9	43.9	13.0
11	191.3	271.7	67.1	95.2	28.2	25.7	36.6	10.8
12	191.3	271.7	61.0	86.6	25.6	21.5	30.5	9.0
13	191.3	271.7	55.4	78.7	23.3	17.9	25.4	7.5
14	191.3	271.7	50.4	71.6	21.2	14.9	21.2	6.3
15	191.3	271.7	45.8	65.1	19.3	12.4	17.6	5.2
16	191.3	271.7	41.6	59.1	17.5	10.3	14.7	4.4
17	191.3	271.7	37.6	53.8	15.9	8.6	12.2	3.6
18	191.3	271.7	34.4	48.9	14.5	7.2	10.2	3.0
19	191.3	271.7	31.3	44.4	13.2	6.0	8.5	2.5
20	191.3	271.7	28.4	40.4	12.0	5.0	7.1	2.1
Total	4,074.9	4,891.3	1,854.9	1,862.31	7.4	1,138.9	939.8	-199.1

Scenarios

Low living standard criteria which are referred as important for farming and rural systems development [27] were observed in the study area, particularly in the terms of education, cash availability and market orientation [19; 20]. Thus, rural extension techniques focused on processing JCL seed via press machines will be very limited. Correspondingly, higher JCL yields hardly can be expected in the upcoming decade due to the combination of biological and economical limits. On the other hand, increasing of the purchasing price from the present USD 0.05 to USD 0.11, e.g., through involvement of private companies in market-chain development (e.g., by contract farming), and/or, support of the farmers with initial costs of plantation via development projects, (e.g., by microcredit), seem to represent two suitable solutions.

The following numbers are obtained if the purchasing price would increase to USD 0.11 per one kg of the harvested seeds: NPV (i = 10 %) = USD 1,867.0 and NPV (i = 20 %) = USD 740.6. Negative NPV value is reached when the discount rate would increase to 55 %. BCR ratio will increase to 1.65 and 2.01 respectively. IRR will increase to 54.67 %. However, increase of the purchasing price depends on many aspects, such as oil prices, input prices, market-chain development etc. Thus, our results can serve as guidance for local policy makers to expect higher probability of JCL adoption among the small-holders in the study area based on the financial benefits from increasing the purchasing price of JCL seeds. One possible solution is to focus on value-added development among the farmers through viable and suitable extension of agricultural production and processing, which was documented by other authors [28].

The second scenario focuses on direct support of farmers with initial costs through development projects, governmental interventions and/or development of microcredit systems. Initial costs are usually considered as the total sum of both financial and non-financial inputs that were invested into establishment of plantation, e.g., till the harvest became relatively stable. In our situation, annual yields became more or less constant since the fifth year of JCL cultivation. Nevertheless, considering

the total value of microcredits per farmer or the total sum of money invested into one farmer through development assistance, only initial costs for the first year are considered in our study. Regarding to this, NPV will be positive after 20 years of cultivation for any discount rate and JCL plantation starts to be profitable for the farmer even during the first five years.

Based on these findings and other surveys [29; 30], combination of agricultural extension in the terms of value-chain development with financial support of initial costs (which should be reduced to purchasing of seedlings only) will represent both a viable and suitable development plan for JCL plantation development in the target region.

Conclusions

JCL cultivation by small-holders in North Tapanuli district can be assumed as a viable and suitable activity, based on both, the ecological requirements of JCL and on the structure of the local farming systems. Labour force and seedlings represent the most important cost and the economic efficiency remains quite low as the purchasing price is too low. Contract farming, ensuring higher purchasing price, and/or, development activities oriented on support to the farmers with initial costs, for example, through microcredits or support of vertical integration of JCL cultivation, can increase the adoption rate of JCL among the local small-holders in North Tapanuli district.

References

1. Openshaw K. A review of Jatropha curcas: an oil plant of unfulfilled promise. Biomas and Bioenergy, vol. 19, 2000, pp.1 – 15.
2. Silitonga A.S., Atabani A.E., Mahlia T.M.I. etc. A review on prospects of Jatropha curcas for biodiesel in Indonesia. Renewable and Sustainable Energy Reviews, vol. 15, 2011, pp. 3733 – 3756.
3. Tiwari A.K., Kumar A., Raheman H. Biodiesel production from Jatropha (**Jatropha curcas**) with high free fatty acids: an optimized process. Biomass Bioenergy, vol. 31, 2007, pp. 569 – 575.
4. Gübitz G.M., Mittelbach M., Trabi M. Exploitation of the tropical seed plant *Jatropha curcas* L. Bioresource Technology, vol. 67, 1999, 73 – 82.
5. Heller J. Physic nut. *Jatropha curcas* L. Promoting the conservation and use of underutilized and neglected crops. Rome: International Plant Genetic Resources Institute, 1996, 66 p.
6. Lin J., Yan F., Tang L. etc. Antitumor effects of curcin from seeds of *Jatropha curcas*. Acta Pharmacologica Sinica, vol. 24, 2003, pp. 241 – 246.
7. Kumar A., Sharma S. An evaluation of multi-purpose oil seed crop for industrial uses (Jatropha curcas L.): A review. Industrial Crops and Products, vol. 28, 2008, p. 1 – 10.
8. Dyer J.C., Stringer L.C., Dougill A.J. *Jatropha curcas*: Sowing local seeds of success in Malawi?: In response to Achten et al. (2010). Journal of Arid Environments, vol. 79, 2012, pp. 107 – 110.
9. Delgado M.J.L., Parado T.E. Potential multipurpose agroforestry crops identified in Mexican tropics. In: Wickens G.E. etc. (Eds.). New crops for food and industry. London: Chapman and Hall, 1989, p. 166 – 173.
10. Sherchan, D.P., Thapa, Y.B., Khadka, R.J., Tiwari, T.P., 1989. Effect of green manure on rice production. PAC Occasional Paper-2, Pakhribas Agricultural Centre. Dhankuta, Koshi Zone, Nepal, p. 12.
11. Das M., Uppal H.S., Singh R. etc. Co-composting of physic nut (*Jatropha curcas*) deoiled cake with rice straw and different animal dung. Bioresource Technology, vol. 102, 2011, pp. 6541 – 6546.
12. Wiesenhütter, J. Use of the physic nut (*Jatropha curcas* L.) to combat desertification and reduce poverty. Bonn: Deutsche GTZ, Germany, 2003. [online] [13.07.2009]. Available at: http://www.underutilized-species.org/documents/PUBLICATIONS/use_of_jatropha_curcas_en.pdf.
13. Faostat. On-Line Statistical Database of the Food and Agricultural Organization of the United Nations. [online] [9.2.2010]. Available at http://apps.fao.org.
14. Sudradjat H.R. Memproduksi Biodiesel Jarak Pagar. Jakarta: Penebar Swadaya, 2006, 108 p.
15. Mkoka C., Shahahan M. "The bumpy road to clean, green fuel". [online] [25.08.2009]. Available at: http://www.scidev.net/en/features/the-bumpy-road-to-clean-green-fuel.html

16. BIPSU. Badan Investasi dan Promosi Sumatera Utara (Investment and Promotion Board of North Sumatra) 2006. [online] [1.2.2008]. Available on-line http://www.bkpmdsumut.go.id.
17. SUDA (Sumatera Utara in Figures). BPS: Statistics of Noth Tapanuli district (1403.12.05), 2004, 282 p.
18. Djojomartono M., Pertiwi S. Present status of information technology utilization in Indonesian agriculture. Proceedings of International conference "First Asian conference for information technology in agriculture", January 24-26, 1998, Wakayama-City, Japan, pp. 9 – 12.
19. Svobodova E., Verner V., Srnec K. etc. Contract farming in tobacco production: Opportunity for small-holders? – Comparative study from North Sumatra. Comparative study from North Sumatra. Proceedings of International conference "Competition for Resources in a Changing World: New Drive for Rural Development", October 7 – 9, 2008, Hohenheim, Germany, online full-paper.
20. Nejedla L., Verner V., Holíková P. etc. Contract farming as a feasible tool for agri-food chain development in pineapple production: Case study of North Tapanuli. Proceedings of International conference "Competition for Resources in a Changing World: New Drive for Rural Development", October 7 – 9, 2008, Hohenheim, Germany, pp. 56.
21. Akcay Y., Uzunoz M. An investment analysis of peach and cherry growing in Turkey. Journal of Applied Sciences, vol. 5, 2005, pp. 1665 – 1668.
22. Lojka B., Lojkova J., Banout J. etc. Performance of an improved fallow system in the Peruvian Amazon—modelling approach. Agroforestry Systems, vol. 72, 2008, pp. 27 – 39.
23. Wang Z., Calderon M.M., Lu Y. Lifecycle assessment of the economic, environmental and energy performance of *Jatropha curcas* L. biodiesel in China. Biomass and Bioenergy, vol. 35, 2011, pp. 2893 – 2902.
24. Hambali E. *Jatropha curcas* as biodiesel feedstock. First edition. Bogor: The National Team for Biofuel Development for Accelerating Poverty Alleviation and Job Creation, 2007. 124 p.
25. Ardiya H. *Jatropha curcas* cultivation in Indonesia. Biodiesel Now/Community, 2006. [online] [12.2.2008]. Available at: http://www.biodieselnow.com/forums/t/11349.aspx?PageIndex=3
26. Fauzi H., Mahoney L.S., Rahman A.A. The link between corporate social performance and financial performance: Evidence from Indonesian companies. Issues in Social and Environmental Accounting, vol. 1, 2007, pp. 149 – 159.
27. Doppler W. (eds.). Farming and rural systems in a changing environment: Resources and livelihood in mountain areas of South East Asia. Weikersheim: Margraf Publishers GmbH, 2006, 443 p.
28. Banout J., Ehl P., Havlik J. etc. Design and performance evaluation of a Double-pass solar driver for drying of red chilli (Capsicum annum L.). Solar Energy, vol. 85, 2011, pp. 506 – 515.
29. Bolwig S., Gibbon P. The economics of smallholder organic contract farming in tropical Africa. World Development, vol. 37, 2009, p. 1094-1104.
30. Barrett C.B., Bachke M.E., Bellemare M.F. etc. Smallholder participation in contract farming: Comparative evidence from five countries. World Development, vol. 40, 2012, pp. 715 – 730.