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Technical and economic feasibility of a guayule commodity chain in Mediterranean Europe

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ABSTRACT

In order to manage the constraints that threaten the supply of natural rubber (NR) from Hevea rubber plantations, the only commercial source of NR, alternative sources were tested in Europe. Guayule, a shrub from the Mexican desert producing natural rubber was found to fit the Mediterranean climate as demonstrated by previous trials setup in France and Spain to assess its agronomic and technological feasibility. The objective of the study was to assess its economic feasibility.

The financial accounts of a European guayule commodity chain model were established from data acquired from previous guayule trials carried out in southern Europe. We developed a guayule commodity chain managed by a farmer for growing biomass, and a processor for extracting rubber and other byproducts (resin, bagasse) in a conceived processing plant. Different simulations were tested to find the most feasible scenario. Based on a 10-year field cultivation period, the breakeven point for the farmer was reached at 214€ ton^{-1} of dry biomass with an average cost of field cultivation of 1924€ year^{-1}. By purchasing biomass at farmer's breakeven point and considering latex as the only final product, the processor breakeven point was reached at latex selling price of 8.16€ kg^{-1} of dry rubber. Otherwise, when adding the parallel production of crude rubber, resin and bagasse through biorefinery process, the latex breakeven point can be lower, at 2.46€ kg^{-1} of dry rubber (plus crude rubber at 2.15€; resin at 2.10€; bagasse at 0.10€); all prices far below current market prices.

Guayule in the Mediterranean was compared to other crops showing that it can play a role as an alternative crop from which the region can benefit to improve its economic development.

1. Introduction

Industrialized countries, particularly in Europe, are known for their intensive industrial sectors, especially with regard to the transportation (manufacturing of cars and tires) and medical sectors (medical and pharmaceutical products). In these sectors, rubber has an important place in the economy (Cinaralp, 2011).

Rubber is produced either as synthetic rubber (SR), synthesized from petroleum by-products, or natural rubber (NR), commonly produced from the tropical tree (*Hevea brasiliensis* (Wild. ex A. Juss.) Müll. Arg.) (Wright et al., 1991; van Beilen and Poirier, 2007). European countries mostly depend on natural rubber imports from tropical Africa and Southeast Asia (Hidde Smit, 2010). Natural rubber has the advantage over synthetic rubber by having low heat-build up, the ability to regain its original shape, and high resiliency (Wright et al., 1991). These unique properties, mainly needed in heavy tire production and in non-allergenic medical products, are not provided by synthetic rubber (De Livonnière, 1997).

In addition, the demand for natural rubber continues growing. NR production was 5 million tons in 1990 and is expected to be 17 million tons by 2025. Between 2009 and 2010, the global consumption of natural rubber in the European Union increased by 2%. Currently, Europe imports an average of 1.2 million tons of NR (IRSG, 2011).

This evidence is accompanied of various constraints and pressures making the future natural rubber supply problematic

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(van Beilen and Poirier, 2007). The main constraints are: (1) oil crises, affecting production and prices of SR; (2) the growing demand of the Chinese market and increasing industrial consumption. Today, China by itself uses almost half of the world NR production (RubberNews.com, 2012); (3) the South-American leaf disease (*Microcyclus ulei*) is potentially capable of destroying all *Hevea* trees in South-East Asia, currently producing 90% of the World NR (L'agora, 2011); and (4) *Hevea* is grown in tropical and equatorial areas with high rainfall. These areas are not extensible (Martin, 1988). Research is therefore very active toward the discovery of new sources of technically and economically feasible rubber. Effective alternatives are rare, and guayule (*Parthenium argentatum* Gray) represents a major opportunity in this regard. Indeed, guayule, a shrub that produces natural rubber in its cells, has a promising potential future to produce natural rubber supplementary to that of the *Hevea* (Martin, 1988), especially for production with of hypoallergenic latex products; e.g. gloves, catheters, condoms (Centre canadien d'hygiène et de sécurité au travail, 2013). There is no evidence of cross-reactivity between *Hevea* allergenic proteins and guayule rubber (Cornish et al., 2001; Palu, 2011).

Today, guayule is only exploited on a commercial scale in the USA by the Yulex Corporation, in Arizona (Yulex, 2012). Its production does not yet exist in the Mediterranean region, but there were attempts in the 1950s in Spain, and in the 1980s in Morocco (Muller, 1946; CSIRO, 1986; Wright et al., 1991).

More recently, the feasibility of guayule growth in two Mediterranean countries (France and Spain) was demonstrated in studies undertaken within the framework of the EU-PEARLS project (Snoeck et al., 2011; van Loo et al., 2012) and different processes were tested to develop latex and crude rubber extraction adapted to the European context (Amor, 2012).

The introduction of guayule in the Mediterranean would be a totally new commodity chain. Therefore, our study aimed to bring more knowledge on its agronomic and technical feasibility before suggesting further development. Environmental, social and economic studies are required to assess the technical and economic aspects of the feasibility of guayule cultivation in the Mediterranean region so as to give information to farmers and manufacturers who would be interested in guayule as a crop.

2. Materials and methods

2.1. Guayule field trials

Experimental guayule fields were planted in 2008 in France and Spain to determine cultivation parameters such as fertilization, irrigation, behavior of imported United States Department of Agriculture (USDA) varieties, biomass, yield, and rubber and resin contents in the various parts of the shrub. Field trials were located in three different areas:

1. In Montpellier (France), CIRAD had implemented variety and fertigation (fertilization + irrigation) trials at the Lavalette site managed by Montpellier SupAgro. This area has quite cold condition for guayule. Average temperature in winter = 5 °C; in summer = 21 °C; total annual rainfall = 776 mm, with 3 dry months ($P_{mm}/T°C < 2$).
2. In Perpignan (France), a trial was planted on fallow land in the plain of Roussillon in collaboration with Claira municipality and the Technology University Institute of Perpignan. Climatic conditions are dryer than Montpellier.
3. In El Molinar farm Cartagena (Spain), trials identical to those of Montpellier were planted under the responsibility of Wageningen University (Netherlands). This area has dry climatic conditions more suitable for guayule cultivation. Average temperature in winter = 10 °C, in summer = 26 °C; total annual rainfall = 300 mm, with 7 dry months ($P_{mm}/T°C < 2$).

Analysis of latex, rubber, resin, and bagasse (fibrous matter that remains after shrubs stalks are crushed to extract the latex) extracted from fresh biomass as well as the development of extraction processes were done in the Cirad laboratory in Montpellier (France). Plant branches were cut with a branch cutter in the field and dipped in an anti-oxidant solution. The biomass was crushed in a laboratory blender, pressed and the plant juice was centrifuged. The latex fraction was coagulated, weighed and dried. Remaining biomass after drying was extracted in an ASE-Dionex equipment with acetone to extract resins, and then again with hexane to extract remaining poly-isoprene.

2.2. Data collection to establish a guayule technical itinerary and setting costs for economic calculation

Based on results from the field trials and on a laboratory scale production pilot plant, we assessed the feasibility of a guayule commodity chain. The commodity chain was divided into two parts: a farmer's field to produce fresh biomass and a pilot plant to extract rubber and resin. The necessary information on costs and cultivation techniques was obtained from agricultural experts in the South of France (Van Kempen and Pérès, 2010) and Spain (García García et al., 2012).

Trials and surveys allowed the comparison of the different agricultural costs in Spain and France. Based on these costs and existing trials results (Snoeck et al., 2011; van Loo et al., 2012), data were deduced for each agricultural activity in the cropping system, and then extrapolated to the scale of 1 ha. These extrapolations were necessary since guayule does not exist in the region for commercial production.

Guayule is a perennial shrub that can live more than 60 years, but after considering trial results in the USA (Coffelt et al., 2009), we used a cropping cycle of 10 years.

Guayule resin has insecticide properties, due to its terpenic components (Gutierrez et al., 1999). Guayule is grown under full sun and is not relatively free of diseases (Hammond and Polhamus, 1965). Consequently, pests and diseases controls were not included in the model. Weed control was required at planting and during first year before shrubs self-shaded the soil.

Table 1 presents the agricultural itinerary and costs for each agricultural activity required to maintain one hectare of Guayule planted in double-rows of 0.35 m × 0.40 m separated by 0.65 m for maintenance facilities (making a total of 50,000 plants ha^{-1}).

For a 10-years cultivation cycle, we considered two different harvesting schedules: annually and biannually. In both cases harvesting started in the second year when the shrubs were well established and the plants had grown through at least one winter. Trials in Montpellier and Cartagena led us to estimate that, with a density of 50,000 plants ha^{-1}, it was possible to produce 14 ton ha^{-1} of dry biomass when harvesting annually and 20 ton ha^{-1} of dry biomass when harvesting biannually (except for the first harvest because the shrub could only produce 14 ton ha^{-1}). At the end of the 10-year cultivation cycle, uprooting the guayule shrubs would be done and the roots also harvested. Roots weight is estimated at 5 ton ha^{-1}, and roots contain 18% of the total rubber weight in the plant (Amor, 2012; Pagneux, 2013). Based on these assumptions, for the entire 10-year cultivation cycle, the total dry biomass weight would be 118 ton ha^{-1} for annual harvesting and 90 ton ha^{-1} for biannual harvesting, including 10% of guayule shrub losses (Sfeir et al., 2012).

Rubber can be extracted in two forms (latex or crude rubber) depending on the method used for extraction: latex is produced by water extraction, while crude rubber is obtained by solvent