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EDITORIAL

Integrating mitigation and adaptation into development: the case of *Jatropha curcas* in sub-Saharan Africa

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Biofuel production is a new economic opportunity for sub-Saharan African countries, given increasing demands for energy on the African continent (Mitchell, 2011). Environmentally, biofuel crops that can grow on marginal land might increase carbon stocks and offer significant greenhouse gas mitigation potential in producer countries. In remote areas, where fossil fuel is expensive and its supplies unreliable, and fuelwood stocks dwindling, *Jatropha curcas* L. (jatropha) biofuel systems may offer a means to improve smallholder livelihoods through energy self-reliance as the oil can be easily extracted in a low-tech manner and used for stoves, lamps, and simple generators. However, a recent article in GCB Bioenergy, focusing on East African smallholder farms, concluded that jatropha is only competitive with fossil fuels when produced in a family labour setting (van Eijck *et al.*, 2012). Such an analysis relies on accurate yield data, but the authors acknowledge that there is considerable uncertainty regarding jatropha yield information from Africa and elsewhere.

With the aim of increasing knowledge and improving information exchange, scientists from the three tropical biofuel projects in the first ERA-ARD call gathered in Nairobi, Kenya from 26 to 27 November 2012 to synthesize the results of 3 years North–South and South–South collaborative research on the sustainability of *J. curcas* L. (jatropha) biofuel systems in sub-Saharan Africa. The central research questions were if, and how jatropha contributes to increasing livelihood resilience in the South while providing significant greenhouse gas savings. The results of this interdisciplinary effort conducted in rural areas of Burkina Faso, Ethiopia, Kenya, Madagascar, Mali, and Tanzania, have increased knowledge about jatropha in six key areas: productivity; climate change mitigation; energy security; impacts on food security; economic viability; and resilience of the social-ecological system as a whole.

Productivity is a key factor, as both the economic viability for farmers integrating jatropha into their land use systems and the climate change mitigation potential are strongly dependent on seed yields. On average, these continue to be low and highly variable in time and space. Although clear progress has been made in understanding environmental requirements (Trabucco *et al.*, 2010) and optimising agronomic practices, there is still limited understanding of the factors determining flowering, fruit and seed production, and thus yield. So far, intercropping jatropha with maize in Tanzania did not result in increased maize yields, but there are indications that food crop yield stability in the context of more irregular rainfall patterns could be improved by incorporating jatropha in multispecies agroforestry systems. Resistance to pests, due to its toxicity, is one of the myths of the jatropha hype of the last decade that has been shattered by our research. We identified many pests and diseases worldwide, investigated their importance in jatropha production systems and made preliminary suggestions for management strategies. The genetic resource base from Central America is currently being exploited for breeding high-yielding varieties with additional traits such as nontoxicity and tolerance to pests and diseases.

On *climate change mitigation*, jatropha plantations offer limited carbon sequestration opportunities due to low biomass production given pruning requirements and short rotation length. Worse, on more than 10% of farms monitored in Mali, conversion of land to jatropha created a carbon debt, leading to a carbon payback time in the order of decades in the case of establishment on long fallow land with sparse trees. Life cycle analysis (LCA) of various jatropha production systems showed that there is mitigation potential in the fossil fuel substitution of the produced biofuel, with more than 40% greenhouse gas savings compared with the fossil benchmark. However, such savings will be realized only if carbon debts by direct and indirect land use change are avoided, and if by-products such as prunings, hulls, and seedcake are either returned to the field or used as an energy feedstock.

From an *energy security* perspective, local use is preferable overproduction for international trade as a fossil fuel substitute. In regions where fossil fuel energy costs are high, small-scale production models with low opportunity costs of land and labour have interesting potential for rural electrification, lighting, cooking, and supplying of stationary or vehicle combustion engines (Rathbauer *et al*., 2012). In general, plant oil-based local energy systems can be a promising option to increase energy security (Wiggins *et al*., 2011).

As to *impacts on food security*, the effect of jatropha is context specific, but, both in areas with land or labour shortage, we observed situations where jatropha increased the risk of food insecurity. Integration into the local food production system as, for example, hedges, alley cropping, small woodlots, and agroforestry systems might offer possibilities to mitigate this risk, but more experiences with mixed systems are needed.

Model calculations have predicted *economic viability* of jatropha systems at oil prices of 70 US dollars per barrel and above, but even with current prices well above this threshold, no viable projects depending solely on jatropha are known. Low returns have led to the abandonment of most commercial large-scale plantations in East Africa and this explains the poor harvesting performance of small-scale jatropha farmers on the African continent. Increased fossil fuel prices, reduced production costs due to economies-of-scale effects, and maximized returns from an optimal use of by-products could change the economic viability of jatropha value chains in the future.

This brings us to the last issue of overall *resilience of the social-ecological system*, where we assessed the opportunities and risks involved when integrating jatropha into African cropping systems. We interviewed hundreds of farmers, and identified the socio-economic and cultural factors that really drive them to adopt or reject jatropha. In Africa, the crop was introduced as a biofuel feedstock mainly through NGOs and private companies. The degree to which these institutions were able to convince farmers played a major role in adoption. Other factors were important for adopting jatropha as well: in general, households classified as food secure, i.e., with sufficient financial, personal, social, and natural assets, engaged in jatropha farming. In particular, membership in farmers' association and increasing area of available cropland per household had a positive influence on adoption. This explains why jatropha cultivation had only a small impact on food security, to date (Ehrensperger *et al*., 2012). We observed that the lengthy harvesting period partly coinciding with the harvest of the main staple food and cash crops is a factor in adoption failure. We also performed the first substantial piece of experimental study on the potential invasiveness of *J. curcas*, which showed that it was unable to establish and spread significantly from deliberate plantings (Negussie *et al*., 2013), assuming farmers do not confuse it with the highly invasive *Jatropha gossypifolia*. Jatropha is suitable for the restoration of degraded land, but this ability needs further exploration. Due to its toxicity, handling and use of jatropha involves human health risks, which start to be addressed by plant breeding.

In conclusion, jatropha has potential to contribute to sustainable rural development in Africa, but, at present, it is not sufficiently productive and profitable to play that role. Strong efforts along the whole value chain from the production of jatropha seed until its end use will be indispensable in achieving this goal.

In the last decade, jatropha research output has boomed from 35 ISI Web of Science reported articles in 2002 to 422 in 2012. The aforementioned challenges are being addressed, but still too many studies are based on modelling efforts that do not use real data, but rather rough estimations or proxies from similar systems. There is now a need for a large, common effort to build a consolidated database of reliable empirical data with fully documented metadata, through participatory data acquisition. This database should focus primarily on yield data, but should also include data on technical, ecological, and socio-economic performance. In this context, knowledge transfer and exchange with rural communities remains an area for improvement in biofuel research on the African continent.

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