"Non-food Crops-to-Industry schemes in EU27"

WP5. Sustainability

D5.3 Report on challenges and conflict areas for non-food crop production systems

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1 Introduction

In the Crops2Industry (in short: C2I) project, Work Package 5 (WP5) aims to assess the sustainability impacts of selected RRM production systems and to identify a ‘core’ list of standards and criteria for the environmental and socio-economic sustainability of selected non-food crops used for biomaterials in a global and country-specific perspective[1].

Although sustainability involves economic, environmental and social issues, the work in WP5 focuses on environmental and social challenges, as the economics of bioenergy and biomaterials are issues of markets and governmental support, and the economic aspects are addressed in WP4.

As part of the WP5 work, both barriers and opportunities of non-food production systems are of interest, and a key task is to identify challenges and conflict areas for non-food crops. This deliverable presents the relevant results of the latter.

Non-food crops in the C2I project are the following:

- Oil crops such as rapeseed, sunflower and linseed
- fiber crops such as flax, hemp, and kenaf
- carbohydrate crops such as maize, potato, and sweet sorghum
- specialty crops such as American cornflower, peppermint, and calendula.

Each of these crop groups has specific challenges and conflicts, but there are also generic issues which are covered in this report.

The work for this report was able to take into account preliminary results from the C2I WP 1 and 6, and also first results from WP 5.1 and 5.2. Furthermore, the authors were fortunate to make use of internal results from other projects on the national level.

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1 Research on the sustainability of non-food crops systems is quite young, so that few studies and very few empirical data are available. In the EU, most of existing data comes from Northern and Central European countries, while the semi-arid or arid climates in Southern European countries restrict the application of results from “Northern” countries which have different soils and climates and use different farming systems.

2 Identification of challenges: barriers for and opportunities of non-food crops

The C2I project defines "challenges" as both barriers to be overcome, and opportunities to be used in order to further the sustainable use of non-food crops in the EU27.

Crops provide renewable materials which can substitute fossil or mineral resources. Furthermore, they can benefit the environment by reducing greenhouse gas (GHG) emissions, cutting waste, improve economic competitiveness of industry through development of new markets and products, and can produce social benefits by stimulating rural communities through establishment of local industries, and revenue. Nevertheless, these potentials need linking between science, agriculture and industry to overcome several barriers.

2.1 Barriers: What hampers the development of non-food crops?

2.1.1 Competition with fossil-based products and value chains

The potential of the bio-economy extends well beyond bioenergy: about 10% of fossil oil is used for chemical production and the remainder for fuel and energy, but the economic value of food and bio-chemicals is approximately equal. A long-term and sustainable market can be envisaged for technologies producing bio-based chemicals, building and fiber materials and pharmaceuticals from plant-based feedstocks which will supplement the demand for bioenergy, and biofuels for transport (Langeveld 2010).

Still, the existing fossil-based material products such as plastics made from fossil crude oil and e.g. energy-intense mineral-based thermal insulation materials are in competition to new bio-based products delivering similar services. An important challenge for the acceptance of bio-based products is not only that they have at least similar – and often superior - characteristics in terms of e.g. degradability, GHG emissions, and water pollution, but also to what extend their **full supply chains** can perform similar to the existing non-bio-based ones.

The bio-based development potential, which basically combines global (market, technology) perspectives with local (land, crops, farming systems) resources and conditions depends on the availability of resources, and adequate infrastructures (Langeveld 2010).

The potential for the production of chemicals, lubricants and other bio-based products in terms of the size of (potential) bio-based markets is showing large variations. Highest market volumes are reported for polymers, solvents and surfactants; highest prices for pharmaceutical ingredients, enzymes and specialties such as solvents and surfactants (Langeveld 2010).

Although the sector of industrial material use of renewable raw material (RRM) is - including wood - still larger than the bio-energy sector, the non-wood shares are rather small, and “new” products made from RRM such as polymers and solvents gain only slowly in market acceptance.

Thus, restrictions in realizing the market potentials for RRM must be seen in the comparatively low development of current supply chains for high-value non-wood RRM, and their downstream processing, including logistics (EC 2009).

This barrier is a bootstrap-type problem: As long as RMM value chains are not developed similar to their competitors, their business-to-business (not customer!) acceptance will be restricted to niche applications where their performance is superior, and their specific costs outside of those niches will remain high, as technology learning and economies of scale depend on increasing markets (EuropaBio 2010).

2.1.2 Regulatory aspects of non-food value chains

Bio-based materials are in competition not only on the product side, but also for their feedstocks which can be used for bioenergy instead. There is currently no European policy framework to support bio-based materials, while existing polities and regulation create higher attraction for using RRM feedstocks for energy uses. High subsidies for energy crops lead to high biomass and land prices that make industrial material use less attractive.

Besides direct support policies for bioenergy and biofuel use, also the current set-up of the European Emission Trading (ETS) system further favors RRM use for energy, as this system treats all bioenergy as carbon neutral, and respective CO_2 credits can be generated from RRM when used in energy facilities regulated under the ETS. Non-energy use of RRM is not eligible under the ETS, though.

As can be seen from that brief summary, a new political-economic framework is needed to rebalance the financial support for energy and industrial material use for biomass (Carus 2011). Unless such a new framework is in place, the market development of material use of RRM in order to provide enough feedstock for the growing bio-based economy, green chemistry and bio-based plastics production will be significantly hampered. This new framework should be linked to the aims to the EU Commission and the Parliament including climate protection, resource efficiency, employment and innovation (CC 2010).

2.1.3 Imports versus domestic supply?

In principle, the supply chains of bio-based products can be organized locally or regionally, but global trade in RRM could stimulate exports from developing countries where RRM potentials are comparatively high.

Still, bio-based value chains require investments in both logistics for large volumes of RRM, and downstream processing into high value-added products.

Developing markets for RRM products needs infrastructure and human capital which is often lacking in developing countries. On the other hand, many developing countries have comparative advantages such as low land and labor costs (SEI 2005).

Thus, the origin of RRM feedstocks will be subject to competition similar to agricultural commodities and imports of such feedstocks to Europe and their "domestic" further processing to higher-value products seems to be at least a partial answer to the further developing of bio-based products.

A bio-based economy that contributes to sustainable development goals requires that feedstock production integrates into existing cropping and farming systems, and uses sustainable production practices both in developed and in developing countries.

While the principle technical potentials of bio-based production systems are quite well defined, their integration in land use systems must be treated with care especially in regions lacking formal protection of land rights (see Section 3.2). Such a development requires innovation frameworks not focusing on fixed technological development but with a more process oriented setup (Langeveld 2010).

2.2 Opportunities of non-food crops

2.2.1 Domestic production and innovative technologies

From a macroeconomic viewpoint, the material use of RRM has advantages: An increasing material use combined with cascading utilization would enable energy uses to be served from the same biomass resource base with additional benefits for resource use, area related output, climate benefits and sustained added-value (PERI 2011).

The area of biofuels is likely to offer increasing opportunities due to rising prices of oil and the growing policy support in order to combat climate change.

One of the major strengths in Europe is the presence of a strong chemicals industry which is an important driver for the development of bio-based products, as many companies aim to diversify their feedstock supply – as has been shown for e.g. Germany (IAP 2010; Loick 2010; Luther 2010; Vorlop 2010), especially for the fermentation industry (ECO 2011).

Another factor is that the variety of cultivated crops in Europe is still rather diverse (including cereals, linseed, potato, sugar beet, etc.) and significant opportunities exist in Eastern Europe in terms of abandoned arable land and residues.

The US, on the other hand, will lead the market in producing 1st and 2nd generation ethanol, and, with a large share of the production of corn and soy, will likely maintain its lead in the production of ligno-cellulosic bio-based materials.

In countries such as Brazil, the large production of sugar cane and the commercialization of bio-renewable carbon sources will be accelerated by the development of bio-refineries producing not only bioethanol, but also bio-based plastics.

GIZ (2011) assumes that the expected impact of the promotion of the use of RRM for non-energy use on the world agricultural markets is limited, but the additional demand for will increase the prices for agricultural goods.

Taken those dynamics into account, the market for RRM must be distinguished into two areas:

- There are markets where RRM are already in large demand, especially the paper, rubber, fiber and textile industries. It is expected that until 2020, these markets will show growth similar to the previous years (GIZ 2011).
- The market for new RRM applications such as bio-plastics has a very high growth potential. The bio-based materials will compete with existing fossil fuel alternatives and depending on the development of oil and natural gas prices, a low feedstock cost might be the only incentive for the use of RRM (GIZ 2011).

Non-food-crops such as non-edible oil plants for material use occupy a niche with relatively small trade volumes. Only a few countries dominate the market, but for producing countries the product is usually an important economic factor. For edible oils, Indonesia and Malaysia have driven the expansion of oil palm cultivation, and Argentina and Brazil, together with the US, dominate the soybean oil market.

India currently dominates the market for castor oil: 80% of the production takes place in intensive irrigated cultivation with high input. The rest comes from rain-fed agriculture on marginal and degraded land. Castor itself is not in competition with food crops. Brazil introduced a “social” seal for castor oil production for biodiesel, not for biomaterials.

Although Europe plays a leading role in research on bio-based products, it is less successful in converting the science-based findings into commercially valuable products.

This is why a so-called demand-based innovation policy war developed: The Lead Market Initiative of the European Commission aims at fostering the emergence of markets with potentially high economic and societal value. It identified six lead market areas to serve as pilot markets for the approach and for the implementation of their action plans.

The initiative promotes and stimulates innovation by strengthening the demand base which in turn should enable enterprises to gain a better return on their innovation efforts. One of the areas selected by the Commission is the area of the bio-based products (CC 2010).

According to the initiative, major opportunities for Europe are

- The presence of a highly developed chemical industry which is an important driver for bio-based products (EC 2009)
- The strong biotechnological and chemistry base in science and industry (EuropaBio 2010; ECO 2011)
- The high diversity of crop cultivation with opportunities to opening-up regional trade with Eastern Europe

The commercialization of biogenic carbon will be accelerated by the development of biorefineries producing bioenergy, biofuels, and bio-based products (STAR-COLIBRI 2011a+b; Vorlop 2010; WWF 2009).

Still, land use for RRM feedstock production will be a key issue to be considered (see Section 3).

2.2.2 Environmental opportunities

The use of bio-based materials is not a "new" concept – it has been discussed and partially implemented already in the late 1970ies, following the first oil-price "crisis", and reappears every decade since then (Anex 2004). Since the early 2000s, though, the concept is researched in more detail regarding its potential for environmental benefits, especially possible greenhouse-gas (GHG) emission reductions (e.g., Dornburg/Lewandowski/Patel 2004; Cunningham et al. 2004; PE 2006; Garraín/Vidal 2007).

There are several opportunities for environmental improvements compared to fossil-based products:

- When grown on land not in competition with other agricultural products, or when using organic residues and wastes, the GHG balance of bio-based materials is typically 50% or less, compared to fossil oil products (Groot/Borén 2010; IFEU 2011; WWF/Novozyme 2009)[2]. On average across all product lines, RMM uses can deliver a GHG saving of 5 - 10 t CO_2eq/ha/a, and if the potential for cascading utilization is included, a reduction of 10 - 20 t CO_2eq/ha/a seems possible (nova 2010).

- Using intercropping, i.e. phasing RRM cultures into the normal agricultural rotation, biomass feedstocks can be produces without land-use competition. Such integrated cropping cycles can contribute to greater habitat diversity, and reduce soil erosion.

- RRM cultivation systems encompass a wide range of commercially exploited niche crops which have a value in terms of agricultural biodiversity: "old" crops appearing uncompetitive with modern high-input cropping systems can become interesting due to their fiber content, reduced agrochemical or water input needs, or ability to be grown on less fertile soils (EIHA 2011; WWF 2009)

2 For a discussion of GHG emissions related to land-use change (LUC), see Section 3.1.3.

- Non-edible perennial grasses and short-rotation coppices have so far been considered mainly for bioenergy use, but these crops are potentially useful also for material use. They have, compared to annual crops, beneficial effects on biodiversity, reduce soil erosion and agrichemical inputs, and could complement more widely grown starch and sugar species (nova 2010).

Moreover, after the useful life of bio-based products, the heating value could still be used for energy, resulting in "cascading" or multiple utilization of RRM (CC 2010; OEKO/IFEU 2010).

2.2.3 Social opportunities

The increasing demand for a sustainable supply of food, raw materials and fuels is the major economic driving force behind growth of the knowledge-based bio-economy (KBBE) which has been significant over the last few decades.

The sector can play an important role in creating economic growth. It is estimated that the European bio-economy has currently an approximate market size of over 2 trillion €, employing around 21.5 million people, and the prospects for further growth are more than promising.

For a variety of reasons it is expected that in the next decade significant changes will take place in this field. There is growing pressure on European companies to diversify their portfolio of products. European companies to diversify their portfolio of products. As an example, some of the largest pulp and paper producers, mainly in Northern-Europe, are conducting cutting-edge research in the field of biofuels and biomaterials (CC 2010).

Table 1: Employment KBBE sector in Europe

Sector Biobased Products	Employment (in 1,000)
Chemicals and plastics	150
Enzymes	5
Biofuels	150

Source: CC (2010)

On the **feedstock supply step** in those chains, the development perspectives of a bio-based economy depend on type and amount of feedstock processed and income generated for smallholders and farm laborers. Here, bio-based products perform clearly superior if they are of domestic origin, and even for imported feedstocks, income from bio-based feedstocks is typically far higher than for non-renewable materials (GIZ 2011).

Employment effects and the added value are typically significantly more positive for the material use of RRM than for the energy recovery of biomass. Calibrated to the same raw material throughput (e.g. in t/year or t/ha), the material use can typically tie up 10-15 times more work force and can generate up to

10 times more added value than energy use (nova 2010). This has been shown for single competing value chains as well as for the entirety of employees in the field of material and energy use of renewables (UBA 2009). It should be noted, though, that a comprehensive analysis and assessment for the broad range of potential RMM uses is not available yet.

The increasing trend of previous years due to renewable resources for material use will be continued. Especially new applications like bio-plastics will be expected a rise of more than 20%. But due to the low market share today, the impacts will be limited. Nevertheless, an increasing demand on the world agricultural markets raises the pressure on existing land and on prices which in turn has income effects:

- Rising prices can improve the economic situation of farmers.
- Increasing production improves the situation of more people and their participation within the value chain.

Both developments increase the purchasing power, especially in rural areas or developing countries. At the same time, increasing purchasing power will improve the food security situation and avoid food scarcity.

It can be assumed that an increased demand of raw materials leads to rising prices, but due to substitutability of products the price rice will be moderate. The use of RRM offers a better utilization of scarce land resources and thus can contribute to poverty reduction (GIZ 2011).

3 Identification of conflict areas: critical environmental and social aspects of non-food crops

3.1 Environmental conflict areas

The environmental impacts of biomass feedstock production for material use can be – similar to bioenergy – either positive or negative, depending on the cultivation system, its location and previous land-use, and the management practices with their effects on biodiversity, soil and water. Furthermore, the overall balance depends on the downstream processing of RRM into useful products, the use phase of such products, and their end-of-life management.

3.1.1 Land Use

Fundamental to the cultivation of RRM is the competition for land – both directly in terms of changing previous land uses with could have been unmanaged natural land such as primary forests, peatland or savannas, and indirectly in converting arable land with the associated displacement of previous agricultural production which implies risks of indirect land use changes (ILUC)[3].

From an environmental point of view, land use is “the” critical issue for any additional cultivation of biomass – disregarding if the feedstock is used for bioenergy, or for bio-based materials.

3.1.2 Biodiversity

Due to the land use associated with biomass feedstock cultivation, the protection of biodiversity is a core concern (Alterra 2010; CBD 2010; Ecory 2009; UNEP-WCMC 2009). The risk of negative effects strongly depending on location, agricultural and forestry practices, previous and indirect land-use, and the conversion systems used in the downstream chain (processing, distribution and consumption).

The international literature on protecting biodiversity (OEKO/IFEU 2010; OEKO/IFEU/CI 2010) as well as the sustainability indicators recently agreed on by the Global Bioenergy Partnership (GBEP 2011) focus on the following two key issues for risk-mitigation strategies:

- Conservation of **areas of significant biodiversity** value, and
- agricultural and forestry **practices** with low negative biodiversity impacts.

In that regard, land use from the cultivation stage is the most quantitatively relevant issue for biomass life-cycles.

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3 It is beyond this paper to discuss ILUC – for a summary of the ongoing discussion, see e.g. Ecofys (2011); Fritsche/Sims/Monti (2010); OEKO (2011), IFPRI (2011); JRC-IE (2011a+b), and Sanchez et al. (2011).

Habitat loss as a result of direct and indirect land-use changes is the major threat to biodiversity, with over 80% of globally threatened birds, mammals and amphibians affected wholly or in part by habitat loss (IFEU/CI/OEKO 2012). Areas of significant biodiversity value are qualified through

- the presence of threatened or endemic species, and
- rare and threatened ecosystems.

These areas are particularly concentrated in the Tropics, but exist also in e.g. Europe, and North America. Prominent factors causing the decline of biodiversity are deforestation, conversion of wetlands, habitat fragmentation and isolation, land-use intensification and overexploitation, invasive species and adverse climate-change impacts.

In addition to land-use change related effects on biodiversity, the land-use itself – i.e. the **cultivation practices and harvesting of biomass** – can be a thread to biodiversity. Monocultures, agrochemical use and extraction practices can threaten biodiversity, and even the use of residues can have significant impacts (Curran/Howes 2011;Riffell 2011).

3.1.3 Emissions of Greenhouse Gases (GHG)

The majority of material uses of RRM typically result in significant GHG savings compared to fossil-fuel or mineral based products – but only **if no land use changes** are included in the analysis. Most studies indicate that RRM delivers GHG reductions at least equal to 1st generation biofuels (see Section 2.2.2), and several RRM systems can have higher GHG benefits than 2nd generation biofuels.

Still, GHG emissions from **both direct and indirect LUC** can dramatically change this:

Direct LUC from converting e.g. tropical forests or peatland has GHG implications in the order of 10 t CO_2eq/ha/a which could completely offset any GHG saving compared to fossil-fuel products, and direct LUC from converting grassland could still imply some 2-3 t CO_2eq/ha/a, thus significantly diminishing potential GHG savings.

If arable land is converted to RRM production, **ILUC effects** could occur in the order of 3-5 t CO_2eq/ha/a which could again reduce most of the potential GHG benefits.

Furthermore, the extraction of **residues** from agriculture (DBFZ/TLL/ILN/ÖKO 2001) and forests (Lippke 2011; Malmsheimer 2011; Whittaker 2011) can significantly impact on the GHG balance due to changes in soil carbon.

Thus, the GHG balance of RRM is a key issue of concern, and further analysis is needed to substantiate that net GHG reductions are achieved, taking into account LUC-related effects.

3.1.4 Environmental risks from GMO

Risks related to the application of genetically modified organisms (GMO) must be evaluated prior to their application for RRM production.

A general assessment covering all GMO is not possible, but with respect to human health and safety as well as environmental risks, policy (CBD 2010) and scientific literature () indicate that a precautionary approach is needed, distinguishing between “white” and “green” biotechnology[4].

Furthermore, an important determinant is how the public perceives GMO-related risks: with regard to the use of GMOs in agriculture, public attitudes in Europe seem to have stabilized in being critical (CC 2010).

3.1.5 Water Availability and Quality

While land availability is the risk mentioned most frequently, freshwater resources can be a similar limiting factor not only for bioenergy (OEKO/IFEU/CI 2010), but also for RRM in general.

A significant share of the freshwater used for irrigation at the moment is wasted and improvements in management practices could free up some capacity in use at the moment (UNEP/OEKO/IEA BioT43 2011). Developing technologies requiring less water will also help (CC 2010).

3.2 Social conflict areas

Managing land competition between RRM for material or energy use and food and animal feed production is one of the key issues of a sustainable bio-based economy. Increased demand for RRM feedstocks can reduce the availability of food and feed crops when converting previously used arable land and the displacement will imply (global) price impacts[5].

For food **importing** countries, higher food prices on the world market will have at least short-term negative impacts on food security, while for food **exporting** countries, the higher prices can be helpful to increase income and, therefore, to reduce poverty and food insecurity.

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4 “White” biotechnology is the production of chemicals and fuels by application in fermentation and enzymatic processes – here, risks seem manageable if safeguards such as multiple barriers and containments as well as adequate waste treatment are applied. “Green” biotechnology comprehends (pre-)production of chemicals in agricultural crops and its risks are far more uncertain, as GMO from “engineered” crops could be released into the environment.

5 Although the intense discussion on food security implications is currently focused on the impacts of biofuel policies (see e.g., FAO 2011; FAO/OECD 2011; HFFA 2011), the issue is not restricted to this domain (nor bioenergy in general) – it is a generic problem of bio-based products if arable land, and edible crops are used as feedstocks.

Farmers, maximizing economic returns, respond by increasing the amount of land cultivated as well as the input application level while poor consumers will rationalize their food purchases.

The consequences of this development (raising prices of food, land, inputs, and increasing numbers of malnourished people) are likely to provoke counteracting reactions. Increasing production costs (and reduced demand) will force farmers to rationalize production (limiting land and input use) while policy makers may take action to restrict crop use for biofuel production (Langeveld 2010).

Also, higher food and feed prices will shift diets to less costly patterns, especially reducing dairy and meat consumption. This in turn will "dampen" the price increase and respective food impacts.

3.2.1 Competition for land and water

Land use has not only effects on biodiversity and GHG emissions, but also direct and indirect implications in the social realm. The social use of land is primarily related to the theme of access to land, water and other natural resources.

Land access is a consequence of land tenure. From a social sustainability perspective, this might be one of the major concerns associated with bioenergy or biomaterials development in some areas (IFEU/CI/OEKO 2012).

The social sustainability of RRM development is directly related to changes in land tenure and access. In many developing countries no land market has been established. The local poor population grow agro-products (food and feed mainly) even without having any kind of legal title or security of the land used.

Similarly, permanent meadows and pasture lands are essential to communities' livelihoods that depend on breeding livestock and consuming livestock sub-products.

When arable lands and lands under permanent crop, permanent meadows and pastures and forest areas are given in concession or leased to private bioenergy investors, the local poor population might lose their capabilities to ensure their life subsistence.

Land to be leased by the state or a domestic authority and/or sold through one-to-one negotiations to individual or corporate investors for biofuel development will require some kind of formal contract or titles from the government. As land tenure as well as local community livelihood conditions are influenced by land customary rights, land acquisition for RRM development must acknowledge these conditions.

Foreign land acquisition is on the rise. The High Level Panel of Experts on Food Security and Nutrition formulated policy recommendations according to land tenure in the following three areas (HLPE 2011):

1. the respective roles of large-scale plantations and of small scale farming, including economic, social, gender and environmental impacts
2. reviewing the existing tools allowing the mapping of available land
3. comparative analysis of tools to align large scale investments with country food security strategies

The report reflects that many problems due to land investment could be dealt with through more effective enforcement of existing policy and legislation on national and local levels. Governments and investors get a better balance by differentiation in terms of sector, level and actors involved (HLPE 2011).

Similarly, the Global Bioenergy Partnership's sustainability indicators compromise land use and food security as key issues, and develop respective methodologies which are applicable also for RRM (GBEP 2011).

4 Conclusions and perspectives

The long term growth potential for bio-based products will depend on their capacity to substitute fossil-based products and to satisfy various end-used requirements at a competitive cost, to create product cycles that are low in terms of GHG emissions and have lower environmental impacts, i.e. generating less waste, less energy and less water (UBA 2009).

The use of RRM has a good image in politics, industry and general public. This is based mainly on the perceived environmental, climate and resource protection, sustainability, health, security of supply through commodity diversification, innovation and employment benefits. This positive image should be used for improving the policy environment for material uses. It would be proposed to develop more product and industry-specific measures. The exception is the potential negative image that might arise from a supposed conflict with the food sector. Information campaigns may be beneficial. Furthermore the positive image should be supported by linking with sustainability criteria (nova 2010).

Access on the material use side arises from market development through market analyses and the resulting marketing activities. Due to emphasis of exports such activities are not just confined to Europe. The energy sector is characterized by highly regulated markets, in opposite to the material use markets, which is characterized by global markets with little public intervention but highly competitive pressure (nova 2010). This result in greater difficulties in providing the material use of biomass with systematic support compared with the more regulated energy sector.

The contribution to rural development is lower in the case of material use. Energy uses offer greater opportunities to raise value-added at the regional level under current support frameworks. Depending on availability and type of RRM, these impact almost entirely in rural areas where they are deployed.

A comprehensive resource management and commodity diversification programs that includes the material use of agricultural raw materials is essential to secure the raw material base of industries. The challenge is to avoid the conflict between food, feed and the technical use of biomass due to the worldwide protein supply.

From the previous analysis, the conclusions of this paper can be summarized as follows:

Non-food crops cultivated on **non**-arable land or land not in competition with food and feed production, and not interfering with nature protection and using land with low carbon soils are favorable options, but social safeguards against land-tenure and land access related risks need consideration.

In general, edible crops such as maize and potato, and crops delivering edible oils do not qualify as sustainable options due to competition with food uses.

Perennial crops seem more favorable than annual cultivation schemes, but biodiversity-related issues concern siting, and management practices.

In that regard, fiber and specialty crops seem most favorable, while carobhydrate and oil crops need careful evaluation.

A key concept to improve the overall sustainability of biomass use is the "cascading" concept: material use first, then recovering the energy content of used bio-based products. This would ensure a high resource efficiency in the use of renewable resources, and would start with single or multiple material uses (recycling economy) followed by energy use at the end of life. The secondary and waste streams are recycled as fully as possible and/or used for energy.

Challenges that need to be successfully addressed in the next years and decades are the low performance of some bio-based plastics (e.g., thermoplastic starch), their relatively high cost for production and processing and the need to minimize agricultural land use and forests impacts in order to avoid competition with food and feed production, and adverse effects on biodiversity and GHG emissions (Shen/Worrell/Patel 2010).

The central environmental aspects and requirements are that the product is long-lasting and that it can be recycled. The most important macroeconomic effects of the material and the bioenergy use of RRM are the employment creation and the generated turnovers along the value added chain.

Currently, producing bio-based products is more expensive compared to traditional production routes. Therefore here is the need for a framework to support bio-based materials (Carus et al. 2011; CC 2010).

With regard to further work, the preparation of a list of sustainability criteria for non-food crops (D 5.4) will take into account the key conflict areas, and will describe a framework of criteria and indicators which could be used in future RRM support schemes.

References

Alterra 2010: Biodiversity and socio-economic impacts of Dutch trade in soya, palm oil and timber; Kamphuis, B. et al.; Alterra report 2155; Wageningen http://content.alterra.wur.nl/Webdocs/PDFFiles/Alterrarapporten/AlterraRapport2155.pdf

Anex, Robert 2004: Something New under the Sun? The Industrial Ecology of Bi-obased Products; in: Journal of Industrial Ecology vol. 7 no. 3-4, p. 1-4

Carus, Michael et al. 2011: Level Playing Field for Bio-based Chemistry and Materi-als; Policy paper on Bio-based Economy in the EU; nova-Institut; Cologne http://www.nova-institut.de/download/Policy-paper

CBD (Convention on Biological Diversity) 2010: Biofuels and Biodiversity - Decisions X/37 of COP10 at Nagoya, Japan, 18-29 October 2010 http://www.cbd.int/doc/decisions/cop-10/cop-10-dec-38-en.pdf

CC (Clever Consult BVBA) 2010: The Knowledge Based Bio-Economy (KBBE) in Europe: Achievements and Challenges; Brussels http://www.bio-economy.be/reports/files/KBBE_2020_BE_presidency.pdf

CI (Copernicus Institute) 2009: Product overview and market projection of emerging bio-based plastics - PRO-BIP; prepared for EPNOE and European Bioplastics; Utrecht University; Utrecht http://www.epnoe.eu/content/download/7670/109501/file/PROBIP2009%20Final%20June%202009.pdf

Cunningham, Bryony et al. 2004: A Sustainability Assessment of a Biolubricant; in: Journal of Industrial Ecology vol. 7 no. 3-4, p. 179-192 DOI: 10.1162/108819803323059460

Curran, Michael P./Howes, Steven W. 2011: Soil disturbance concerns regarding the use of forest biomass as a source of energy: Examples from Pacific Northwestern North America; in: Biomass and Bioenergy vol. 35 no. 11, pp. 4547-4556

DBFZ (Deutsches BiomasseForschungsZentrum)/TLL (Thüringer Landesanstalt für Landwirtschaft)/INL (Institut für Nachhaltige Landbewirtschaftung e.V.)/ÖKO (Öko-Institut - Institut für angewandte Ökologie e.V.) 2011: Basisinformationen für eine nachhaltige Nutzung landwirtschaftlicher Reststoffe zur Bioenergiebereitstellung; Schriftenreihe „Energetische Biomassenutzung“ Band 2; Leipzig http://www.energetische-biomassenutzung.de/fileadmin/user_upload/Downloads/Ver%C3%B6ffentlichungen/02_Basisinformationen_Reststoffe_web.pdf

DEFRA (Department for Environment, Food and Rural Affairs) 2004: A strategy for non-food crops and uses. Creating value from renewable materials; London

Dornburg, Veronika/Lewandowski, Iris/Patel, Martin 2004: Comparing the Land Re-quirements, Energy Savings, and Greenhouse Gas Emissions Reduction of Bio-based Polymers and Bioenergy: An Analysis and System Extension of Life-Cycle Assessment Studies; in: Journal of Industrial Ecology vol. 7 no. 3-4, p. 93-116

EC (European Commission) 2009: Taking bio-based from promise to market - Measures to promote the market introduction of innovative bio-based products; A report from the Ad-hoc Advisory Group for Bio-based Products in the framework of the European Commission's Lead Market Initiative; Brussels http://ec.europa.eu/enterprise/sectors/biotechnology/files/docs/bio_based_from_promise_to_market_en.pdf

ECO (ECO SYS GmbH) 2011: Die Wettbewerbsfähigkeit der Bundesrepublik Deutschland als Standort für die Fermentationsindustrie im internationalen Vergleich; i.A. der FNR; Schopfheim http://www.fnr-server.de/ftp/pdf/berichte/22003310.pdf

Ecofys 2011: Indirect effects of biofuel production - Overview prepared for GBEP; Utrecht http://www.globalbioenergy.org/uploads/media/1105_ECOFYS_-_Indirect_effects_of_biofuel_production.pdf

Ecorys 2009: Study on understanding the causes of biodiversity loss and the policy assessment framework; prepared for DG ENV; Rotterdam http://ec.europa.eu/environment/enveco/biodiversity/pdf/causes_biodiv_loss.pdf

EIHA (European Industrial Hemp Association) 2011: Hemp Fibres for Green Products – An assessment of life cycle studies on hemp fibre applications; Huerth http://www.eiha.org/attach/639/11-07-07_META-LCA_Hemp_Fibre_Products.pdf

EuropaBio (European Associaton for Bioindustries) 2010: Building a Bio-based Economy for Europe in 2020; Brussels http://www.bio-economy.be/reports/files/building-a-bio-based-economy-for-Europe-in-2020.pdf

FAO (Food and Agriculture Organization of the United Nations) 2011: The State of Food Insecurity in the World - How does international price volatility affect domestic economies and food security?; Rome http://www.fao.org/docrep/014/i2330e/i2330e.pdf

FAO (Food and Agriculture Organization of the United Nations)/OECD (Organization for Economic Cooperation and Development) 2011: Price Volatility in Food and Agricultural Markets: Policy Responses. Policy Report including contributions by FAO, IFAD, IMF, OECD, UNCTAD, WFP, the World Bank, the WTO, IFPRI and the UN HLTF; Rome/Paris http://ictsd.org/downloads/2011/05/finalg20report.pdf

Fritsche, Uwe R./Sims, Ralph/Monti, Andrea 2010: Direct and indirect land-use competition issues for energy crops and their sustainable production – an overview; in: Biofuels, Bioproducts and Biorefineries vol. 4 pp. 692–704

Garraín, Daniel/Vidal, Rosario/Franco, Vicente 2007: Land use in LCA of biomaterials; Castellón http://www.gid.uji.es/docs/articles/Garrain_07_02.pdf

GBEP (Global Bioenergy Partnership) 2011: GBEP Sustainability indicators for bioenergy; Rome http://www.globalbioenergy.org/fileadmin/user_upload/gbep/docs/2011_events/12th_TF_Sustainability_WashingtonDC_17-20_May_2011/GBEP_List_of_Indicators.pdf

GIZ (Deutsche Gesellschaft für Internationale Zusammenarbeit) 2011: Nachwachsende Rohstoffe für die stoffliche Nutzung – Auswirkungen auf Entwicklungs- und Schwellenländer. Am Beispiel von Palmkernöl, Kokosöl, Rizinusöl, Naturkautschuk und Jute; im Auftrag des BMZ; Eschborn

Groot, Wim J./Borén, Tobias 2010: Life cycle assessment of the manufacture of lactide and PLA biopolymers from sugarcane in Thailand; in: Int J Life Cycle Assess vol. 15 no. 9, p. 970-984

HFFA (Humboldt Forum for Food and Agriculture e. V.) 2011: The economics of Rumpelstiltskin - Why speculation is not a prime cause of high and volatile international agricultural commodity prices: An economic analysis of the 2007-08 price spike; Witzke, H./Noleppa, S.; Berlin http://hffa.info/files/speculationandprices.pdf

HLPE (High Level Panel of Experts) 2011: Land tenure and international investments in agriculture; Report by the High Level Panel of Experts on Food Security and Nutrition of the Committee on World Food Security; Rome http://www.fao.org/fileadmin/user_upload/hlpe/hlpe_documents/HLPE-Land-tenure-and-international-investments-in-agriculture-2011.pdf

IAP (Fraunhofer-Institut für Angewandte Polymerforschung) 2010: Neue Cellulose-materialien und Verarbeitungswege; Fink, Hans-Peter/Ebeling, Horst; Beitrag zum Projekttag "Stoffliche Biomassenutzung" 15.12.2010 Berlin http://www.fnr-server.de/cms35/fileadmin/allgemein/images/veranstaltungen/Stoffliche_Biomassenutzung/fink7.pdf

IFEU (Institute for Energy and Environmental Research)/CI (Copernicus Institute)/OEKO (Oeko-Institut - Institute for applied ecology) 2012: Global Assessments and Guidelines for Sustainable Liquid Biofuels Production in Developing Countries; GEF Targeted Research Project executed by UNEP/FAO/UNIDO; Heidelberg/Utrecht/Darmstadt (forthcoming)

IFEU (Institut für Energie- und Umweltforschung) 2011: Ökobilanz von Danone Activia-Verpackungen aus Polystyrol und Polylactid; i.A. von Danone; Heidelberg http://www.natuerlicher-verpackt.de/files/oekobilanz-danone-activia.pdf

FPRI (International Food Policy Research Institute) 2011: Assessing the Land Use Change Consequences of European Biofuel Policies; prepared for EC DG TRADE; Washington DC
http://trade.ec.europa.eu/doclib/docs/2011/october/tradoc_148289.pdf

JRC-IE (EC Joint Research Centre - Institute for Energy) 2011a: Critical issues in estimating ILUC emisssion - Outcomes of an expert consultation 9-10 November 2010, Ispra (Italy); Marelli, Luisa/Mulligan, Declan/Edwards, Robert; report JRC 64429/EUR 24816 EN; Ispra
http://iet.jrc.ec.europa.eu/sites/default/files/EU_report_24816.pdf

JRC-IE (EC Joint Research Centre - Institute for Energy) 2011b: Estimate of GHG emissions from global land use change scenarios, Marelli, L. et al.; report JRC

64430/EUR 24817 EN; Ispra
http://iet.jrc.ec.europa.eu/sites/default/files/Technical_Note_EU24817.pdf

Kuntz, K.-R. 2010: Untersuchungen zur Verbesserung der technologischen und ökonomischen Voraussetzungen für den Einsatz von Einjahrespflanzen als Rohstoff für die Holzwerkstoffindustrie; Abschlussbericht FNR-Vorhaben FKZ 22020006; Gülzow http://www.fnr-server.de/ftp/pdf/berichte/22020006.pdf

Langeveld, J./Dixon, J. 2010: Development perspectives of the biobased economy: The need for a system approach; Working paper Wageningen University; Wageningen

Lippke B. et al 2011: Life cycle impacts of forest management and wood utilization on carbon mitigation: knowns and unknowns; in: Carbon Management vol. 2 no. 3, pp. 303–333 http://www.future-science.com/doi/pdf/10.4155/cmt.11.24

Loick, Hubertus 2010: Innovative und am Markt akzeptierte Biowertstoffe vom Acker; Beitrag zum Projekttag "Stoffliche Biomassenutzung" am 15.12.2010 Berlin
http://www.fnr-server.de/cms35/fileadmin/allgemein/images/veranstaltungen/Stoffliche_Biomassenutzung/loick5.pdf

Luther, Rolf 2010: Biobasierte Schmierstoffe in Windkraftanlagen – Ein starkes Team; Beitrag zum BMELV/FNR-Projekttag "Stoffliche Biomassenutzung - Mit Innovationen den Wirtschaftsstandort Deutschland stärken" am 15.12.2010 in Berlin
http://www.fnr-server.de/cms35/fileadmin/allgemein/images/veranstaltungen/Stoffliche_Biomassenutzung/luther_fuchs6.pdf

Malmsheimer, R. et al. 2011: Managing Forests because Carbon Matters: Integrating Energy, Products, and Land Management Policy; Journal of Forestry Oct/Nov (supplement) http://www.safnet.org/documents/JOFSupplement.pdf

nova (nova Institut) 2010: The development of instruments to support the material use of renewable raw materials in Germany; Cologne

OEKO (Oeko-Institut - Institute for Applied Ecology) 2011: Indirect Land Use Change and Biofuels; Fritsche, U./Wiegmann, K.; study prepared for the European Parliament's Committee on Environment, Public Health and Food Safety; Brussels
http://www.europarl.europa.eu/activities/committees/studies/download.do?language=en&file=35128

OEKO (Oeko-Institut - Institute for applied ecology)/IFEU (Institute for Energy and Environmental Research) 2010: Sustainable Bioenergy: Summarizing Final Report of the research project "Development of strategies and sustainability standards for the certification of biomass for international trade", sponsored by the German Federal Ministry for Environment (BMU) through the German Federal Environment Agency (UBA); Darmstadt/Heidelberg http://www.umweltdaten.de/publikationen/fpdf-l/3961.pdf

OEKO (Oeko-Institut)/IFEU (Institute for Energy and Environmental Research)/CI (Copernicus Institute) 2010: Bioenergy Environmental Impact Analysis (BIAS) - Conceptual Framework; study prepared for FAO; Environment and Natural Resources Working Paper 46; Rome http://www.fao.org/docrep/013/am303e/am303e00.pdf

PE (PE International) 2006: Auswertung von Studien zur ökologischen Betrachtung von nachwachsenden Rohstoffen bei einer stofflichen Nutzung; Deimlin, S. u.a., i.A. der FNR (FKZ 114-50.10.0236/06-E); Stuttgart

PERI (Political Economy Research Institute, University of Massachusetts) 2011: The Economic Benefits of a Green Chemical Industry in the United States; Amherst

Riffell, Sam et al. 2011: Biofuel harvests, coarse woody debris, and biodiversity – A meta-analysis; in: Forest Ecology and Management vol. 261 (2011), pp. 878–887

Sanchez, Susan et al. 2011: Accounting for Indirect Land Use Change in the Life Cycle Assessment of Biofuel Supply Chains; in: Journal of the Royal Society Interface (forthcoming)

SEI (Stockholm Environmental Institute)/UNIDO (United Nations Industrial Development Organization) 2005: Industrial Biotechnology and Biomass Utilization. Prospects and Challenges for the Developing World; Stockholm/Vienna

Shen, L./Worrell, E./Patel, M. 2010: Present and Future Development in plastic from biomass; in: Biofuels, Bioprod. Bioref. Vol. 4 pp. 25–40

STAR-COLIBRI (Strategic Targets for 2020 Collaboration Initiative on Biorefineries) 2011a: European Biorefinery Joint Strategic Research Roadmap; Brussels http://www.star-colibri.eu/files/files/roadmap-web.pdf

STAR-COLIBRI (Strategic Targets for 2020 Collaboration Initiative on Biorefineries) 2011b: Joint European Biorefinery Vision for 2030; Brussels http://www.star-colibri.eu/files/files/vision-web.pdf

UBA (Umweltbundesamt) 2009: Utilisation of renewable raw materials; Jering, A./Günther, J.; commissioned by the European Topic Centre on Sustainable Consumption and Production; EEA Brochure x/2009; Copenhagen

UNEP (United Nations Environment Programme)/OEKO (Oeko-Institut – Institute for applied ecology)/IEA BioT43 (IEA Bioenergy Task 43) 2011: The Bioenergy and Water Nexus - Full Report; Paris http://www.unep.fr/energy/bioenergy/documents/pdf/Assessing%20Biofuels-full%20report-Web.pdf

UNEP-WCMC (United Nations Environment Programme World Conservation Monitoring Centre) 2009: The impacts of biofuel production on biodiversity: A review of the current literature; Campbell, Alison/Doswald, Nathalie; Cambridge http://www.unep-wcmc.org/medialibrary/2011/03/11/628e876f/The%20impacts%20of%20biofuel%20production%20on%20biodiversity_final_for%20release.pdf

Vorlop, Klaus-Dieter 2010: Innovative Technologien, Verfahren und Produkte mit Entwicklungspotenzial; Beitrag zum Projekttag "Stoffliche Biomassenutzung"

15.12.2010 Berlin http://www.fnr-server.de/cms35/fileadmin/allgemein/pdf/veranstaltungen/Projekttag/Vorlop_12_2010.pdf

Whittaker, Carly et al. 2011: Energy and greenhouse gas balance of the use of forest residues for bioenergy production in the UK; in: Biomass and Bioenergy vol. 35 no. 11, pp. 4581-4594

WWF (World-Wide Fund for Nature) 2009: Industrial biotechnology - More than green fuel in a dirty economy?; Copenhagen http://www.bio-economy.be/reports/files/wwf_biotech.pdf

WWF (World-Wide Fund for Nature)/Novozyme 2009: GHG Emission Reductions With Industrial Biotechnology: Assessing the Opportunities; Buttazzoni, Marco; pre-pared for WWF Denmark and Novozyme; Copenhagen http://assets.panda.org/downloads/wwf_biotech_technical_report.pdf