Bioenergy and Food Security

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Summary

Bioenergy is biomass converted for energy applications in the heat, transport or electricity sectors. It can be obtained from food and feed crops, non-food crops, woody forest based sources and various types of wastes and residues, including the biodegradable fractions of municipal or industrial wastes. An expansion of bioenergy production from agricultural and forestry sources leads to concerns over land use management and governance within a context of growing demands for food, resulting from increasing global population and wealth. Furthermore, some predictions suggest that climate change will negatively impact agricultural yields. So it is important to consider the potential impacts of expanded bioenergy production on food security.

There are up to 1,4 Bha of suitable land available for sustainable rain-fed agriculture without taking forests and urban uses into account (Background Chapter 1). This is more than enough to expand the present agricultural area to fulfil growing demands for food production, which is calculated to need an additional 130-219 Mha after taking lower yield increases and possible negative effects of climate change into account. The remaining land should be sufficient to allow bioenergy to make a considerable contribution to global energy needs. The land required for bioenergy and food production does not constitute a zero-sum game: there are various synergies and multiple uses, including the use of residues and wastes. With sufficient investment and proper management, bioenergy can also be employed to improve an additional area of up to 600 Mha of degraded land and make it productive again.

Thus, land availability per se does not constrain a significant increase in bioenergy production. However, food insecurity still affects nearly one billion people in less developed countries, of which roughly 20-30% live in urban areas and 70-80% in rural areas; for such persons the effects of bioenergy production need to be carefully considered. The key question is therefore not about managing competition for land between energy and food, but rather about finding the most valuable and productive entry points for incorporating bioenergy into human and natural landscapes (Background Chapter 1).

Food security is commonly measured across four dimensions: availability, access, utilisation and stability. Food prices are the major factor contributing to food insecurity among the urban poor. There is no overall body of evidence showing a strong causal relation between bioenergy production and food price increases although bioenergy expansion can be a minor contributor to higher food prices when multiple pressures coincide. On the other hand, flexibility in bioenergy or food production from the same land or crop can contribute to long term market and price stability for producers.

With respect to the rural poor, higher food prices can be a benefit where they can sell their surplus. There is also evidence that bioenergy could enhance food availability, access, utilisation and stability for the rural poor. Production of bioenergy can potentially provide energy security and boost economic development by improving agricultural management, infrastructure, food preservation, education and market development. Good governance is required to ensure that poor farmers and other rural residents benefit from expanded bioenergy production. The impacts are generally site-specific so it is important to compare governance options and policy measures in specific settings in order to insure that food security is improved.

From recent evidence, including case studies collected in this report, we conclude that bioenergy can be implemented in ways that have neutral or positive impacts on food production and security. Bioenergy can contribute to:

- decreased price volatility, resulting from a diversification of revenue sources from agricultural and forest-based commodities, reducing supply risks and increasing rural income, with associated benefits on farm income and investment;
- agricultural and land use infrastructure development through investments for biomass feedstock and bioenergy systems;
- rural economic development, supported by local energy availability and development of improved value chains, market linkages and infrastructure;
- providing a flexible, market-based system that can adjust the use of biomass for food or energy in times of abundance or scarcity

The goal is to realise bioenergy expansion that is compatible with improved food security and environmental sustainability. This requires multidisciplinary, applied research across the entire bioenergy chain from resources and feedstocks through conversion, transportation and end-use. Implementation of best practices in bioenergy systems also rely on good governance at local, national and global levels, including capacity-building in developing countries and the design of supportive regulations, certification schemes, investment structures and financing. Transparent communication methods are needed to ensure that trust is built within the diverse communities of agricultural practice and associated stakeholder groups, so as to maximise the benefits from positive synergies between expanded bioenergy and food security around the world.

1. Introduction

This cross-cutting chapter describes and analyses the relation with and potential impacts of bioenergy on food security and gives recommendations for policy, research, capacity-building and communication. In reviewing these impacts, we distinguish between global factors (e.g. commodity price shifts, international trade) and localised impacts, whose significance is context-dependent and may also differ in urban vs. rural settings. We draw on relevant elements in the SCOPE report background chapters and also consider linkages, synergies and conflicts between bioenergy expansion and food security.

1.1. Relevance

Access to affordable and reliable energy is a precondition for improved food security, and independent of its origin, increased energy availability will improve food security (FAO, 2008a; FAO 2008b; FAO, 2012). Bioenergy that is based on crops, however, has a special relation to food security which - especially in the case of agricultural land dedicated to biofuels production - is perceived as a trade-off between food, feed and fuel and much debated around the world. The debate is characterised by diverse opinions, and includes some ill-informed statements (Landeweerd et al., 2012b, Michaelopoulos et al., 2011). This chapter provides science-based information aimed at improving the decision making process for sustainable bioenergy production. It will, where possible, provide recommendations to avoid negative effects and stimulate positive effects of bioenergy production on food security.

Bioenergy uses biomass to produce electricity, transportation fuels, or heat. Biomass for energy can be obtained from food crops; non-food crops, woody or forest-based sources and various types of wastes or residues, including the biodegradable fraction of municipal or industrial wastes. Crop and forest biomass use leads to concerns over land use management and governance, yet bioenergy production does not lead to a zero sum game of land use: use of agricultural or industrial residues used for energy generally do not increase land use, while some dedicated bioenergy (non-food) crops may be grown on marginal lands where annual food crops cannot grow. Even whencurrent crop land is used, bioenergy production can stimulate rural development and lead to *increased* food security through income enhancement and general improvements in local infrastructure; improvement of supply chain logistics and market access and improvement of food safety and health through better access to energy. Positive effects such as increased economic security for rural communities and improved farm and regional capacity for crop production are already demonstrated in the agriculture systems of developed and developing countries (Background Chapter 8). In the United States biofuel production from maize brought utilisation of underused capacity, and stimulated the development of production capacity in other regions, while in Brazil bioethanol from sugarcane provided an opportunity to expand overall agricultural capacity. In both countries it helped to increase national energy independence [Chapter 2, 7 and 14; Box 1; Box 5]. Negative effects can occur for many reasons for example when decisions for biofuel crops were not well accompanied by agricultural adaptation (in case a new crop is not yet domesticated) and/or not followed by effective market infrastructure or governance, such as the premature commercial introduction of Jatropha in some African countries (von Maltitz et

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al, 2014; see also Box 2). In these cases local citizens were left with reduced food supplies, while energy crops did not produce the expected increases in revenues for those affected (Cotula et al., 2008; Gordon-Maclean et al., 2009; German et al, 2011). Also soil quality (including removal of nutrients, biological activity and issues related to water retention) has to be considered, especially when using residues. This has already led to standards and guidelines developed in the US for corn (Chapter 7) and sugar cane in South Africa (Meyer, 2010). Policy measures such as mandates can be used to create an initial market for bioenergy but should be considered carefully before implementation to ensure compatibility with food security, particularly in terms of avoiding local disruption of food supplies.

However, effective policy necessitates well-informed policy makers and public support for bioenergy promoting measures (Landeweerd, 2012a,b). The food versus fuel debate has greatly influenced decision makers and publics. Real concerns have sometimes been met with inappropriate generalisations and strongly emotive pictures by organisations that have positioned themselves against biofuels or bioenergy development (Rosillo-Calle and Johnson, 2010). This has negatively influenced public support. In a recent qualitative and quantitative study in The Netherlands, 75% of respondents were strongly in favour of sustainable development. However, while they had a positive association with the concept of using bioresources for all sorts of materials, they had a negative association with using biomass for energy and fuels (Van der Veen et al, 2013; CSG, 2013). Public engagement is shown to increase knowledge and improve development of informed opinions (Stirling 2008, 2012; Fiorini 2009). However, it is difficult to engage people in the complexity of sustainable development, climate change, food security and bioenergy. Investigating the role of emotions it was found that people react differently to different images. Four different emotional viewpoints to a transition to a biobased economy were identified. Figure one shows the pictures that gave positive and negative emotive reactions of 'principled optimists' (Sleenhoff et al., 2014). This may give some clues as to how to improve communication on these issues, but we also need more studies and insights into different cultural and global (ethical) viewpoints to use this to better engage publics.

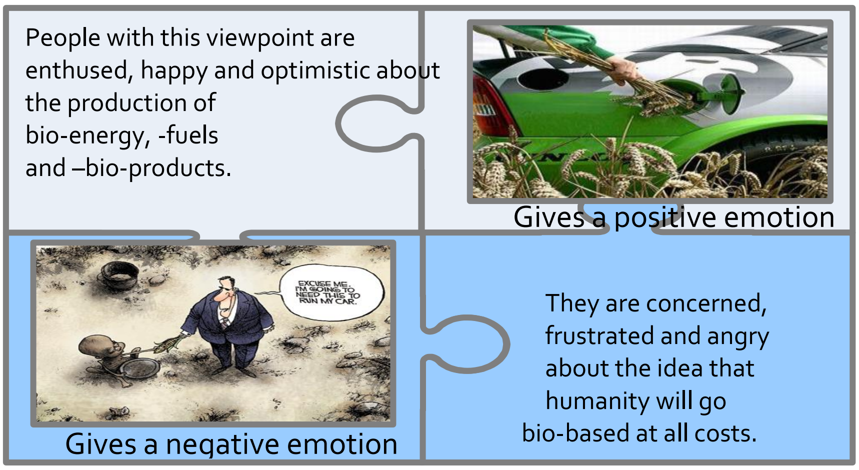

Figure 1. Images give different emotional reactions to different people. Emotional reactions of 'principled optimists' to media released pictures (Sleenhoff et al., 2014)

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1.2. What is food security?

The Food and Agriculture Organization (FAO)[2] [7]defines food security as a condition that "exists when all people, at all times, have physical and economic *access* to sufficient, safe and *nutritious* food to meet their dietary needs and food preferences for an active and healthy life". Distinct components that can be used to analyse and monitor food security have been identified as: availability, access, utilisation and stability. Food *in*security is closely related to poverty; fluctuations in international commodity markets, misguided foreign policies or actions; domestic policies undermining food production; poor infrastructure; degraded land; and especially civil conflict and war. In 2.2 and 2.3 we will assess the bioenergy development in relation to the four components of food security and consider how positive impacts on food security might be promoted and negative impacts avoided.

1.3. Ethical principles

Independent of the origin of energy, increased energy availability is often a necessary condition for improving food security (FAO, 2008a; FAO, 2008b). If expanded production and provision of *bioenergy* can help improve food security, and it is within our power and reasonable to do so, then it is prudent and just for nations in a position to help to stimulate such pathways to do so (EGE, 2008, Nuffield, 2011).

why & ethics:
bioenergy – food security

Energy security is a precondition for improved food security, and independent of the origin of the energy, increased energy availability will improve food security (UN)

If *bioenergy* can help improve food security it is our duty to stimulate this (EGE, 2008; Nuffield, 2011.)

Food is seen as a basic human right[1] and sustainability is considered as a general aim to provide for future generations [Brundlandt, 1987]. Both food security and sustainability have been defined by the European Group on Ethics, (2008) and the Nuffield Council (2011) as ethical goals for which *responsible action is implied* [report 'opinion 24']. These goals and actions are based on notions of human dignity and a universal need for justice as conceived by these groups. The latter can be further divided into distributive justice (which guarantees the right to food on an equitable and fair basis); social justice (which protects the most disadvantaged in society); equal opportunities (which guarantee fair trade at national and international levels) and intergenerational justice (which safeguards the interests of future generations). . The latest monitoring reports of the millennium and sustainability goals of the United Nations show decreased poverty and increased sustainable practices; however 1 in 8 people (0,9 B people) are still chronically

[1] derived from the International Covenant on Economic, Social and Cultural Rights (ICESCR), recognizing the "right to an adequate standard of living, including adequate food," as well as the "fundamental right to be free from hunger."

hungry and increased population growth in developing countries (especially Africa)requires further efforts in sustainable energy production. Roughly 20-30 % of people with food insecurity (180-270 M) live in urban areas and are mainly affected by (high) food prices, but 70-80% (630-720 M) of food insecurity problems occur in rural areas where interaction with bioenergy can make a great difference (FAO, 2010; United Nations, 2010; FAO, IFAD and WFP, 2013).

1.4.Beyond categoric rejection of bioenergy.

In the last five years several developments have brought a new perspective on the relation between bioenergy and food security. In the second half of 2008 and the start of 2009, the vast majority of reports in the literature considered the interaction between food and bioenergy in a negative context (SCOPE Biofuels, 2009 published as Howarth and Bringezu, 2009). For instance, this previous SCOPE report stated (page 77): "The use of food crop species to produce biofuels will remain problematic as the world struggles to increase food production to better feed an increasing population that currently includes roughly 1 billion who are severely underfed. Special energy crops are not an effective way to avoid competition with food production, because they too require land, water, nutrients, and other inputs and thus compete with food production." Since that time, however, substantial new understanding has developed. In particular:

- Although biofuels policies create new sources of demand for agricultural products, this is also true for supply. Production of biofuels from grain crops, therefore, has clear potential to lower price spikes associated to supply shocks (Wright, 2011; Locke et al., 2013), and likely did so in the US during the drought of 2012.
- Africa has potential to meet both its food and fuel needs from biomass, neither of which occurs today. "In particular, biofuel production could help unlock Southern Africa's latent potential and positively increase food production if it brings investment in land, infrastructure, and human resources." (Diaz-Chavez, 2010; GSB, 2010).
- As pointed out by Lynd and Woods: "Consideration of the impact of bioenergy on African food security has tended to focus on land competition and to overlook bioenergy's marked potential to promote rural economic development. Yet potentially productive land is plentiful in Africa whereas lack of rural development is the most important cause of hunger". (Chapter 1; Lynd and Woods, 2011).
- A study of 15 small bioenergy initiatives in developing countries found that production of staple foods did not appear to be affected (PAC, 2009).
- Estimates of the magnitude of land clearing due to ILUC have decreased by an order of magnitude for bioenergy feedstocks grown on cropland, are likely yet smaller for bioenergy grown on converted pastureland, and in practice the growth of biofuels has been accompanied by increased food availability worldwide. Whereas the magnitude of estimated ILUC effects was formerly thought to be large enough to negate the GHG emission benefits of an otherwise low-emitting biomass-based fuel supply chain, this is no longer the case. (Chapter 10).

- Currently pasture land makes a small contribution to global supplies of dietary protein and calories (Chapter 1). The intensification potential of pasture land in some locations may be much simpler and offer comparatively greater benefits than cropland (Sheehan et al., in review). Consistent with this, most of the 673 million hectares seen as available for bioenergy production by the World Wildlife Fund (2011) is on land currently being used for low-intensity grazing.
- There is clear potential to grow bioenergy feedstocks on land that is not suited to produce annual food crops (Somerville et al., 2010, see also background chapter).
- Langeveld et al. (2013) concluded that there is little reason to expect that biofuel production will lead to substantial reductions of areas of food/feed production. Indeed, between 2000 and 2010, during which substantial expansion of bioenergy occurred, net harvested area for purposes other than biofuel production increased.
- A detailed comparison of five global agroeconomic models by Lotze-Campen et al. (2014) found the impact of high demand (108 EJ by 2050) for second generation (lignocellulose-based) feedstocks on global food prices to be modest. For all but one of the models, changes in the amount of cropland are relatively small and currently unmanaged land is by far the largest land category used for traditional bioenergy production.

The results above do not imply that bioenergy cannot or will not have negative impacts on food security. Rather they imply that bioenergy need not necessarily have such negative impacts, and, for many of the studies, that net positive impacts on food security are possible. Consistent with this, several substantial studies (Rosilo-Calle, 2010; Achterbosch et al., 2013; Hamelinck, 2013) support a nuanced view in which the impact of bioenergy on food security can be positive or negative depending on how it is implemented and the local circumstances, and net benefits to food security can be achieved with strong governance and policy support.

1.5.Background and preconditions.

- ✓ There is ***enough land available*** for substantial bioenergy production and increased food demand (2.2)
- ✓ There is no clear causal relation between bioenergy/biofuels and food insecurity
- ✓ Poorly designed or poorly implemented policies and institutions can effect food security positively or negatively *and* ***hence bioenergy development needs good governance and flexibility in implementation***
- ✓ If we identify positive impacts of bioenergy on food security it is ***our duty*** to stimulate this

This chapter is based on the premise that there is enough arable land available in principle to feed the expected world population for the foreseeable future (2035-2050) *and* provide for a substantial part of energy through biomass utilisation, as developed in Chapter 1, Land Use and Biomass. In principle, since there seems to be enough land available for both food/feed demands as well as bioenergy demand, we could continue to use traditional food crops for bioenergy to some extent. However, good land management is crucial while opportunities to improve conditions of marginal, low productivity lands by adapted (energy) crops should where possible, be considered. In addition, we should optimise integrated biorefinery designs and reduce and use wastes and residues for bioenergy (Chapter 5, Modern Bioenergy Conversion, Utilization and Systems), while addressing long term soil quality through recycling of nutrients (Chapter 11, Hydrology, Water and Soil). To compensate for this additional growth in resource use, we should intensify the use of low productivity pasture-land and make use of (part of) the available area of pasture, which is estimated to be around 900 Mha, for multipurpose agriculture (Chapter 1).

Uneven distribution and various comparative advantages in food production require appropriate distribution through trade, good governance and supportive policy measures to avoid food insecurity. Yield increases and appropriate land management are necessary (Chapter 2). This demands special attention, while also being indicative of opportunities, in developing countries where yields are presently poor. Chapter 13 on Economics and Policy shows that there is no direct causal relation between food security and bioenergy production. Social development could be stimulated by local bioenergy production (Chapter 8), leading to the conclusion that the production of bioenergy, where appropriate applications have been chosen and are well-managed, can be beneficial for food security.

With proper management, bioenergy expansion can increase local rural development, providing jobs more effectively and/or at lower costs, which increases, income and education. For example labour use efficiency can be improved through additional harvests for bioenergy production during the year. Biofuel industry can improve food chains and (local) infrastructure. These are all factors with a positive impact on food access for the poor (Landeweerd et al., 2012 b; Moraes, 2011). The trade-off here is that with mechanization and loss of economic opportunities the rural population tends to migrate to urban centers. Such a shift could have great consequences, if urban societies do not provide income opportunities, as food security in urban areas is mainly affected by food price. Other measures are required to alleviate food insecurity in urban poor communities where incomes do not grow adequately.

2. Key findings

2.1. Food security, bioenergy, land availability and biomass resources

2.1.1. Increasing crop production versus increased demand for primary foodstuffs

FAO (1996) defined food security as "all people, at all times, have physical and economic access to sufficient, safe, and nutritious food to meet their dietary needs and food preferences for an active and healthy life" A first order requirement to have the potential to realize this definition is that the amount of primary food and feedstuffs that is produced equals or exceeds demand. The world's major crops saw year on year increases in yield per hectare for most of the last half of the 20th Century, leading to surpluses and declines in cost in real terms (FAO (2), 2006). Although significant proportions of the populations were malnourished, this was not only a problem of production, but also of downstream factors and disposable income. However, the projected rate of increase in global demand (2.4% per year) may now be outstripping these increases in production. The low productivity growth could be induced by the long period of declining real food prices that did not provide an incentive to invest in technological change and led to an underinvestment in public agricultural R&D (Banse et al, 2008). Increasing food prices could reverse this trend. Furthermore, yield gaps around the world and especially in developing countries remain high and allow for catching up and increasing yields especially in developing countries where food security is a problem. The increase in demand is due not only to a rising population, but also to changes in the global average diet driven by urbanization, higher incomes (especially in Asia), and policy choices in some countries (Foley et al, 2011). If this leads to increasing costs of primary foodstuffs in real terms, it will affect economic access for the world's poorest, and will arguably be a factor in increasing social unrest (Hsiang et al, 2011; Otto et al, 2009).

Projected rate of increase in global demand for food and feedstuffs: **2.4%** per year

- However, yields in main food crops (maize, rice, wheat, and soybean) are increasing at lower rates: 1.6%, 1.0%, 0.9%, and 1.3% per year, respectively
- Demand could outstrip production by 30%, requiring an additional **130 - 219 Mha by 2050**
- The demand for land might be less if price induced innovation occurs, yield-gaps might be closed more rapidly due to higher prices or public\private underinvestment in agricultural R&D increases

Maize, rice, wheat, and soybean currently provide nearly two-thirds of global agricultural calories (Rao et al. 2013). A global analysis showed that yields of these crops are increasing at 1.6%, 1.0%, 0.9%, and 1.3% per year, non-compounding, respectively, which is less than the 2.4% per year rate required to double global production by 2050. It has been projected that if historical rates of yield improvement are maintained through 2050, then demand will outstrip production by 30% or just over 1 billion tonnes of these four key primary foodstuffs. Meeting this demand would require recruitment of an additional 130 - 219 Mha, unless we can either improve on historical rates of yield improvement in yield per hectare (Alexandratos and Bruinsma, 2012; Rao et al., 2013) or be capable of producing two crops in the same harvesting season. There are positive examples. In Brazil double cropping of soybean and maize has increased significantly in response to improved prices, increasing yields without increasing land use. The demand for land will be less if price induced innovation occurs as real food prices will increase. This has occurred in the Black Sea region in recent years which has now become a major feed grain, vegetable oil and wheat export region. Yield-gaps might be closed more rapidly due to higher prices or public\private investment in agricultural R&D and when food prices are back on the political agenda. However, the capacity to increase yield, even at historical rates of improvement might be questioned, especially in regions where yield is already high, or where other factors hinder yield improvements. While maize, and also sugar cane yields continue to increase (Chapter 2), rates of improvement in rice have declined and stalled in wheat (Long & Ort, 2010; Ray et al. 2012). This may be attributed to the fact that the genetic approaches to improving yield potential in these crops can be shown to be reaching their biological limits (Long & Ort, 2010). One option to increase worldwide production is to make more intensive, high input use of extensive areas of arable land in Africa where yields are far from potential in all farming regions. Batidzirai et al. (2006) predicted a seven-fold increase in Mozambique's productivity with moderate use of agricultural technologies, such as fertilizers, pesticides, selected seeds, and large-scale harvesting practices. Bekunda et al. (2009) note how the use of fertilizers, improved seeds and extensive agricultural extension have doubled and even tripled cereal crop yields at local levels in 10 African countries. In addition, bioenergy could help develop better storage and food conservation, avoiding post-harvest losses (Background Chapter 14).

There are new prospects for increasing the yields of these crops, but they require the use and acceptance of genetic engineering (Zhu et al. 2010), which as shown in Chapter 2 have contributed significantly to yield improvement in maize over the last decade. As a first approximation it would appear that diversion of these primary foodstuffs to biofuel would exacerbate price and pressure to clear land. However, the experience of maize ethanol in the USA over the past 10 years should cause a reconsideration (Chapter 2). Maize in this region, unlike the other primary foodstuffs, has seen a 30% increase in yield per hectare, which was likely (at least in part) supported by this additional market (Box 5). Further, in the 2012 drought, additional land planted to corn provided a buffer to shortages and grain was diverted away from ethanol production (Chapter 2). As discussed in Chapter 2, this increase has been sufficient to not only offset all the grain diverted into ethanol production, but also allowed an increase in exports and sales to other markets. Other adjustments independent of biofuel use have also contributed to sustaining adequate feed grain supplies. In particular, growth in poultry and pork consumption compared to beef has resulted in less grain being used per kg of meat production. So while this diversion has undoubtedly had some impact on price it also stimulated for modifications in US renewable fuel policy. Increased production has also increased residue in high yielding fields, that can be diverted into cellulosic fuel production, which stimulates additional investment in yield improvement.

2.1.2. Global change

Three elements of global change affect food crop production and interact with bioenergy viz. climate change (temperature and soil moisture), atmospheric change (rising CO_2 and tropospheric ozone), and land degradation (salinization, desertification, fertility loss). IPCC (2013) asserts that the median of studies indicate that climate change will cause a 0 to -2.5% decline in maize and wheat yields per decade and none in rice and soybean. This appears small in relation to historic rates of yield improvement per decade in these crops. But there are several caveats in relation to a range of extreme events that may on balance become more common, like extreme weather events and adverse altered pest and disease incidence. Tropospheric ozone, which is today some ten times pre-industrial levels, is already estimated to cause yield losses of around 10% in these crops and levels may increase by increasing temperatures and nitrogen oxide emissions, especially in SE Asia. By contrast empirical field scale enrichment of CO_2 to anticipated 2050 levels increased the yield of rice, wheat and soybean (C3 crops) by about 15%, but did not affect maize (C4) yield (Long et al., 2006; Ainsworth et al., 2008). About 607Mha of farm land worldwide has become so degraded that it is no longer farmed. Not only can degraded and marginal land be used for bioenergy feedstock production, but by doing so, the land can be rehabilitated and improved. Simpson et al (2009) describe how for example switchgrass improves soil quality and productivity, but grasses in general are restorative in many circumstances, including where salinity is a problem. Chapter 9 provides an overview of the positive and negative effects of growing crops on degraded land which concludes that few positive influences on biodiversity and ecosystem services result from biofuels development. Such positive outcomes are of limited spatial and taxonomic scale. Biofuels-mediated improvements might occur when already degraded lands are rehabilitated with non-native feedstocks, but such changes in habitat structure and ecosystem function support few and mostly common species of native flora and fauna. Even the limited evidence of perennial grass crops favoring certain bird species indicates the requirement of special management regimes.

Three elements of global change affect food crop production and interact with bioenergy:

- Climate change: small **decline in yields**; extreme events, increases in other areas
- Atmospheric change: tropospheric ozone may reduce yields but rising CO_2 may **increase yields**
- Land degradation: bioenergy can help to **recover land for** food production that became degraded
- Overall: increased yield potential at higher latitudes but reduced yields and food production in semi-arid tropics

Tufekcioglu et al. (2003 cited in UNEP, 2009) note that switchgrass' below ground biomass can be eight times higher than the above ground biomass and that it produces 55% more total soil organic carbon than corn/soy bean over two rotations. Hendricks and Bushnell (2008) list several halophytic crops that thrive in soils degraded by salinization. They could be used as bioenergy feedstock while removing the excess salt from the soil by allowing improved water infiltration resulting in salt removal from the root zone (leaching) and rendering it suitable for food crops again. There is a limit, though, since recovery in biomass is not quantitatively significant when lands are seriously salt-affected. A considerable area of land (ca 25 M ha) has also been degraded by industrial and mining activities and are contaminated with heavy metals (Haferburg and Kothe, 2012). Crops like willow that absorb these pollutants can be grown for bioenergy rendering the soils suitable for food crops or grazing again (FAO/UNEP, 2011). In addition to improving the soil/ land resource, Lynd and Woods (2011) argue that use of such land for the production of bioenergy from non-food crops can have numerous positive impacts, particularly through introduction of technologies useful for food production, local job creation, enhanced energy self-sufficiency, improved food security and economic status that reduces conflict.

Overall, global change will have negative impacts and the expansion of bioenergy will certainly contribute to the development of new technologies for local and regional adaptation to climate change, potentially opening up other agricultural development pathways.

2.1.3. Land and water availability

In order to achieve 2050 food and feed consumption projections (above), based on the most recent FAO studies (Alexandratos and Bruinsma, 2012; Conforti, 2011), water and land will not be major constraints at global level. Projections for 2050 indicate a growth of 60 % on agricultural output over the levels of 2005/07, distributed as following: 89 % for oil crops (133 Ktons oil equivalent), 76 % for meats (197 Ktons), 75 % for sugar crops (146 Ktons sugar equivalent) and 46 % for cereals (941 Ktons).

As specified in Chapter 1, according to Alexandratos and Bruinsma (2012) this output increase would require an additional 130 Mha. More aggressive projections on demand indicate a larger additional land requirement: 219 Mha assuming that historical levels of improvement of yield per unit land area continue (Ray et al. 2013). Around 90 % of the 130 million will be met by Latin America and Sub-Sahara Africa, while developed countries will be responsible for the majority of the land decline (estimated as 63 Mha). Out of the 130 Mha increase, FAO (2012) is projecting 19 Mha additional irrigated lands, which is a 6 % increase compared to the 2005/07 level. FAO projections are focused mainly in meeting food and feed demand. A very conservative scenario of diversion of these crops into biofuels was assumed. Therefore, projected land demand in this FAO analysis is driven mainly by food and feed markets.

FAO also estimates that 34% percent of total world surface is “to some extent” prime and good land for rain fed agriculture (4,5 Bha). Of this area, 1,26 Bha is already in crop production and 1,8 Bha is forest, protected areas or urban. This leaves an apparent 1.4 Bha that could be used in principle for crop production. About 26% of this land is Latin America, 32% in Sub-Sahara Africa and most of the remainder in Europe, Oceania, Canada and the USA.

The projected 130 to 219 Mha expansion needed for 2050, therefore, will not face constraints in terms of land availability. Water availability does not appear to be a limiting factor at the global level for this needed agricultural expansion, although there are regions that face strong water shortages. One uncertainty is around the water required to support more productive crops in the future. Although, continuation of the historical rates of yield increase is assumed, water use efficiency has remained unchanged, for example if yield is increased 1% per year, so may be water use. On the other hand, improvements in harvest index, agronomy, pest management, land quality and irrigation technology not only correlate with better yields, but also improve efficiency in irrigation water use. However, it may mean that some areas classified as suitable for rainfed agriculture by FAO might in the future require some irrigation to support the improved yield potential.

Irrigated agriculture is expected to expand less than in the past. FAO (2012) projects a net increase of 19 Mha by 2050 from a total of 300 Mha irrigated today 'While the small increases projected for Latin America and Sub-Saharan Africa (<4%) appear sustainable, those for E & N Africa and S. Asia (52% and 40%) do not, based on FAO estimates. Where unsustainable use of irrigation, causing salinization, in poor communities is driven by the need to generate a livelihood, bioenergy crops that do not require irrigation or that can tolerate salinity (see Chapter 2 for examples) could provide more sustainable livelihoods in these particular locations.

Land availability for rain-fed agriculture: **4.5 B ha very suitable/suitable**

- Expected **need** for growing food and feed demands: **130-219 Mha**
- Available, excluding land already in use for agriculture (1,3 Bha), forests and protected land (1,8 Bha): **1,4 Bha, of which 955 Mha pasture land**
- Additional land is strongly concentrated in **Latin America and Sub-Sahara Africa**, and used predominately for animal grazing. Developed countries also have land available but agricultural area is expected to remain stable

At global level, land is not a constraint but availability is concentrated in two main regions

2.2 Interplay between Bioenergy and Food Security

2.2.1 Analysis of food security in the bioenergy context

How can bioenergy be produced within the context of increasing food security? The food crisis of 2007-08 led to the re-emergence of the old food-versus-fuel debate, raising concerns about biofuels competing with food security (Sagar and Kartha, 2007). Biofuel and bioenergy use can increase pressure on the global demand for biomass unless a commensurate supply response is initiated. A clear distinction was noted, however, between highly productive crops and applications, particularly sugarcane ethanol in Brazil, vs. the relatively inefficient production of biodiesel from soya and rapeseed (Rosillo-Calle and Johnson, 2010). Some empirical studies suggest that biofuels contributed to 10-15% of food prices increases . This is in direct contrast to previous studies (Mitchell, 2008; World Bank President, Robert Zoellick, NPR, 2008; Rosegrant et al, 2006) which had stated a much higher impact on food prices arising from the conventional biofuel programs of Brazil, USA, EU and others, e.g. up to 75% of the 2008 increase in food prices. However, analysis on observed data has not identified an impact at these levels. Figure 2 projects the estimated price impacts based on different scenarios for 2020 and 2030.

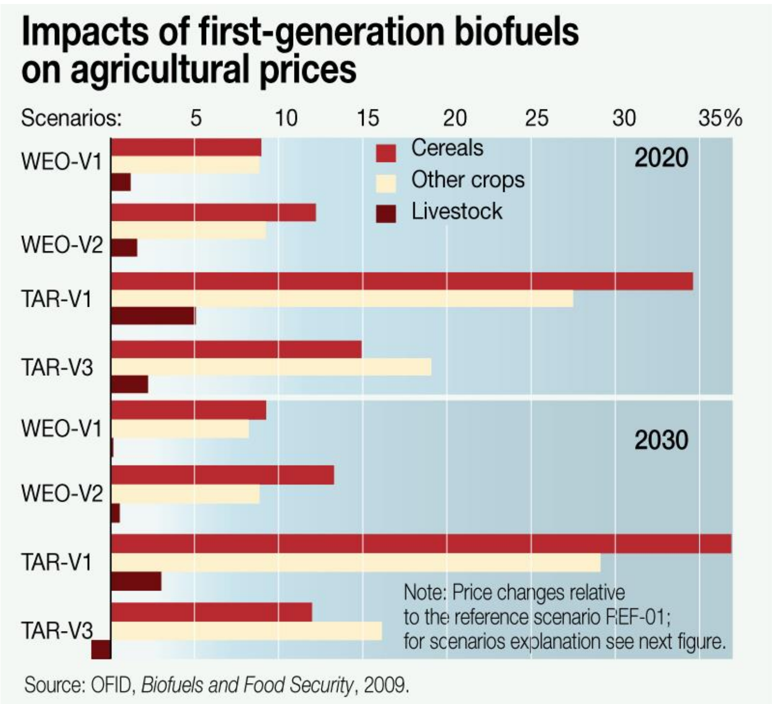

Figure 2: Impacts of conventional biofuel production on agricultural prices in different scenario's (UNEP, GRID Arendal, 2011, http://www.grida.no/publications/vg/biofuels/ viewed at 27-1-2014)

Recent econometric evidence by Baffles and Dennis (2013) found that oil prices were the main driver of the higher food prices. Van Ittersum (2011) suggests that agricultural output will need to triple between 2010 and 2050, if global agricultural biomass were to deliver 10 per cent of global energy use by 2050. More fundamental objections to increased demand for biomass for energy are voiced by Krausmann et al, (2013) who state that with a 250 EJ/y bioenergy scenario by 2050

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HANPP[2] would increase from 27-29% to 44% and they caution against a further increase. Higher *food prices* are in general considered as negative for food security in poor urban regions and therefore bioenergy and especially biofuels from food crops has become unpopular, particularly where government policy apparently directly stimulates markets. However, the analysis is not so simple, for example higher food prices might also lead to higher farm income in poor rural areas, with subsequent investments in the agricultural system leading to higher food security over the long run (Achterbosch, et al., 2013). Direct and indirect or more dynamic effects might have different impacts on food security over various time-scales. The FAO has divided the analysis and monitoring of food security into four categories (FAO (2), 2006):

1. *Availability* of sufficient quantities of food of appropriate quality, supplied through domestic production or imports (including food aid). Available land and food production play an important role.

2. *Access* by individuals to adequate resources for acquiring appropriate foods for a nutritious diet. Here, land, income, infrastructure, conflicts and consumer prices play an important role

3. *Utilisation:* Utilisation of food through adequate diet, clean water, sanitation and health care to reach a state of nutritional well-being where all physiological needs are met. Storage, infrastructure, income and local consumer food prices play an important role.

4. *Stability:* To be food secure, a population, household or individual must have access to adequate food at all times. Macro-economic conditions play an important role in stability.

2.2.2 Availability

The production of biomass for bioenergy affects the goal of availability dimension of food security in several ways. A direct effect is through land use: if agricultural land is used for the production of biomass for bioenergy, it is no longer available for food production, and thus in principle, it negatively affects food production. While (global) land availability has been shown to not be a constraint, local availability may become an issue. Double cropping, reduction in fallow periods, and complimentary crop-shifting within cropping systems help counteract or eliminate these effects. This has occurred in some regions in soy, maize and sugarcane production. The availability question is more complex than the food versus fuel debate suggests. For example, in Brazilian tropical agriculture, second crops are becoming more and more important. Very large areas are grown with soy bean followed by corn in the same year. Both crops can be used either for food or biofuel, but the amount of land is the same as if it was only one crop for only one use. Rising prices, in turn, may lead certain producers to grow more food, until a new equilibrium is found. The dynamic effects are initiated by the higher farm prices and increased income allows investments in irrigation, better varieties, fertiliser, education and increased efficiency. All these investments increase food production and food availability. The increased availability of high quality energy sources also has a positive effect on agricultural production, especially in areas where there is energy poverty. The expansion of agro-industries can offer a low-cost energy feedstock in the form of wastes or residues, together with enhanced agricultural system

[2] Human appropriation of net primary productivity

performance, thereby addressing both energy access and food security (see Chapter 14 on Energy Access). Another important way to obtain synergies is through implementing integrated food-energy systems, which offer valuable climate benefits alongside their economic benefits (Bogdanski, 2012).

2.2.3 Access

Access refers to the relationship between food prices and disposable income, but also to access to land and other natural resources for subsistence or smaller-scale producers, where resources are used to generate income, provide energy services or food. Prices play a role in that food may be available, but too expensive for poor households to purchase in sufficient quantities. Any additional income generated by bioenergy production raises the purchasing power of the household, and also results in a lower share of food costs in household expenditures. Where bioenergy production is organised at small-scale and/or household-level, the access benefits could accrue directly. However, where bioenergy is led by large companies, such as sugarcane in Brazil, the costs and benefits will differ, depending on the degree of mechanisation and the extent to which displacement of small farmers occurs. To some extent these shifts are a basic feature of industrialising societies and are not closely related to bioenergy *per se*.

The impact on food access for farmers and land owners will be negatively affected by the higher food prices and positively by their higher income. Bioenergy will have a negative effect on food access for consumers that do not increase their income from bioenergy production if they do not share in increased prosperity. These effects are clearly different for the urban poor and the rural poor (that are farmers). Carefully designed and implemented policy measures are needed to avoid the adverse effects of food price shocks. In addition to feedstock diversification and safety nets for the most vulnerable, a certain level of flexibility will thus be needed in bioenergy policies to respond to food supply disruptions or price shocks. The need for such policies is not restricted only to the case of bioenergy production from land.

2.2.4 Utilisation

Utilisation refers to what kind of food people consume; quality and diversity is an important nutritional concern. This also relates to prices and income, but other factors, such as health care, access to clean water, education, knowledge about nutrition etc., are important as well. There is a weak link between bioenergy and utilisation. An important health issue might be the ‘switching’ from the use of traditional low quality fuels and inefficient and unhealthy cooking and heating devices which lead to indoor pollution at rates that result in the mortality of nearly 4 million women and young children prematurely every year (Bruce et al, 2006, Conway, 2012 and Chapter 8). Modern small-scale bioenergy technologies such as advanced/efficient cook stoves, biogas for cooking and village electrification, biomass gasifiers and bagasse based co-generation systems for decentralized power generation, and energy for (clean) water pumping, can provide energy for rural communities with energy services that also promote rural development (IEA, 2011; Woods, 2006 and Chapter 8). Such improved systems could increase food safety (by avoiding microtoxins and aflotoxins through better prepared and stored food)(PAC, 2013). Another perspective that is valuable for utilisation is that of landscape ecology, in which integrated management methods can improve diversity and resilience (Dale et al, 2013).

2.2.5 Stability and resilience

Stability refers to the fact that "a population, household or individual must have access to adequate food at all times. They should not risk losing access to food as a consequence of sudden shocks from weather or social factors or chronic economic and social conditions" (FAO (1), 2006). An improvement in the *functioning of markets* leads to more stability (Achterbosch et al. 2013). Policy corrections can help to restore the imbalance in supply and demand when crops are used for biofuels, such as illustrated in Thailand for palm oil (Box 4). Markets are closely related to prices and income as well. They determine food and biofuel prices, and consequently household incomes. It is important to understand how markets can contribute to a stable household income, allowing a stable access to food and good quality nutrition. Three ways in which households can achieve this have been identified: inclusion into value chains, opportunities of small to medium enterprises (SMEs) and local value adding. In general, producing biomass and fuels for the energy market in addition to the food market diversifies revenue sources for the agricultural sector and from a portfolio and risk point of view this might reduce risk and increase income. Whenever the food market is weak (low prices) for farmers they can sell more to the energy market. Producing energy locally might also increase energy self-sufficiency which might increase resilience when energy markets get tight. This occurred in the developed market of the United States, where commodity use for bioenergy helped to significantly increase rural incomes. Assato and Moraes (2011) also noted that jobs generated by the expansion of the sugarcane industry in Brazil and related sectors have played a key role in reducing rural migration. (Chapter 8). Similarly, Satolo and Bacchi (2013) assessed the effects of the sugarcane sector expansion over municipal per capita GDP, noting that the GDP for one municipality and that of its satellite neighbours grew from 24% in 2000 to 55% in 2010. (Chapter 8).

Biofuel developments may contribute to an overall improvement in *macroeconomic performance* and living standards because biofuels production may generate growth (i.e., multiplier or spill-over effects) to the rest of the economy. This might benefit both the urban and rural poor. Improving the investment climate is crucial: achieving these growth linkages requires strict control and governance of the proposed biomass investment; only then can the stability dimension of food security can be addressed (Achterbosch et al. 2013). It is important to ensure that the investment strengthens the rural economy and that the local population benefits from additional economic activity, value retention and employment. Four issues can facilitate this. First, investments in biomass production for bioenergy may have spill-over effects that benefit food production. Second, enabling government policies need to be in place to ensure biomass production for bioenergy benefit rural communities. Third, farmers' organisations may play an important role in this ensuring equity and good extension. Finally, land tenure rules need to be in place to ensure that rural communities continue to have access to land for their livelihoods or are adequately compensated for their land.

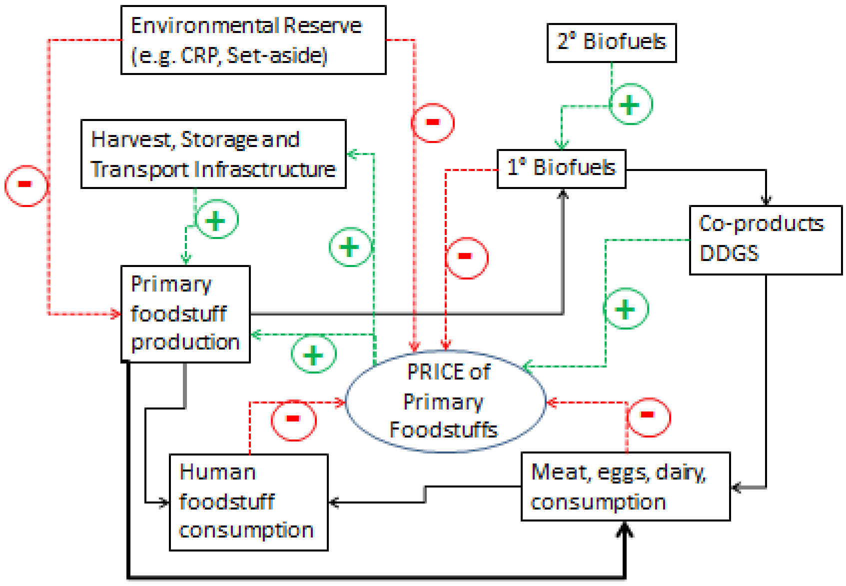

Fig 3. **Simplified relation of food prices to bioenergy.** Black lines show flow of material. Green + dotted lines show an effect that promotes production and investment, and decreases price through increased supply. Red - lines show factors that depress production or increase price, by decreasing amounts available for human consumption.

2.3 Causal linkages: bioenergy, rural/agricultural development and food security

Bioenergy development need not become a zero sum game for land use that results in either energy or food. Poverty and hunger predominantly result from inadequate supplies of food and from a lack of income. The majority of the rural poor depend on farming and grazing, many poor use a large portion of their income for food. Increased income among rural poor reduces food insecurity as does increased food production. Where farming is possible, bioenergy production can stimulate rural development broadly and result in increased food security by improving rural incomes. Agricultural industries support larger numbers of jobs than many other types per unit of investment capital, and development in the agricultural sector is especially productive of jobs and income growth in the poorest regions and countries (Cervantes-Godoy and Dewbre, 2010).

Rural development initiates a process of sustainable intensification of land use in which the production potential of the landscape is more closely approached, and new, previously unanticipated or constrained agricultural enterprises evolve. Increasing capacity for food production has characterized the agriculture of developed nations, and is reflected in more recent case studies (Brazilian case study and others, Chapter Case studies). Potential positive and negative effects from locally optimal biomass energy projects are identified in their relation to causes of food insecurity in Table 1.

Poorly conceived or developed bioenergy projects may have adverse effects on rural populations and landscapes as well. Bioenergy is not necessarily universally prudent. The most obvious concerns are exploitive, unsustainable land use and/or the creation of extractive businesses aimed primarily at exports, which may offer few advantages for rural populations other than additional cash income. Metrics and indicators of food security are not necessarily the same as the underlying causes of food security. Thurow and Kilman (2009) identify the following key causes: poverty; local food production being undermined by cheaper subsidized imports; poorly developed infrastructure (physical, institutional, and human); degraded land; conflict and instability; and loss of access to land. Commentary on each of these causative factors is presented in Table 1.

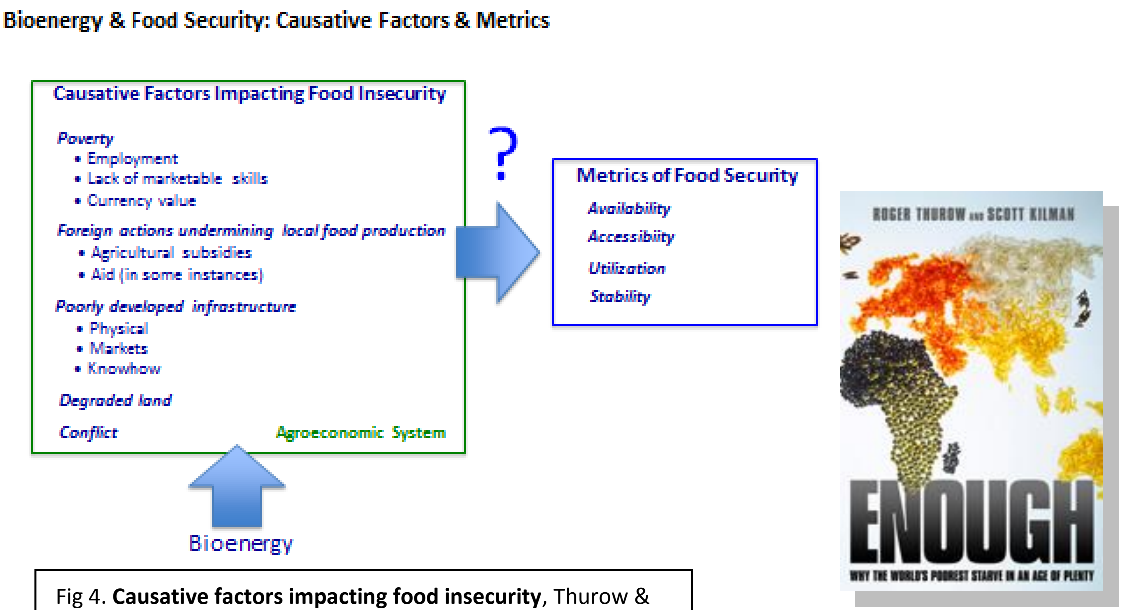

Fig 4. **Causative factors impacting food insecurity**, Thurow & Kilman (2009, http://enoughthebook.com/)

Causes of Food Insecurity	Positive	Negative	Value maximization strategies
Poverty			
Lack of employment and income	Substantial job creation, stimulation of rural development and market economy	Labor force could be drawn away from food production at critical times. Bioenergy development can be done without local employment benefits.	Emphasize local employment, products using local materials and methods of distributing benefits
Lack of saleable products	New markets for producers.	Lost opportunities (see loss of land access)	Local equity in bioenergy systems as well as feedstock production.
Lack of marketable skills, underdeveloped human capital	Opportunities to learn improved agricultural skills and other forms of human development	Labor becomes indentured (in the case of large or medium-scale estates).	Education, extension.
Low currency value (higher priced imported goods)	Improved buying power if energy imports are meaningfully reduced.	Bioenergy (fuels) produced by foreign companies for export only	Some caution should be taken with foreign investment that is intended only for foreign markets (land grabbing effects), however, there is a time dimension: ; if the country has no blending policy or technical infrastructure then it should be perfectly ok to export and then use the new agro-industrial capacity to start up national policies for domestic use.
High food prices	Increased resilience --> less price volatility	If good land is scarce, devoting land to bioenergy reduces food supply and increases prices (positive for producers), negative for consumers).	Agricultural development and sustainable intensification. Use land of little agricultural value for energy production. For those countries that have fossil fuel subsidies, make revenue-neutral shift to food subsidies for the poor.
Loss of Access to Land	Employment income mitigates need to grow food	Bioenergy concentrates good land in a few hands, rural poor shifted to marginal lands Displaced persons have their livelihood affected	Land tenure for rural poor must be recognised. Land registry systems to avoid inequitable transfers of land. Promote Economic development in rural areas

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Local food and feed production undermined by cheaper, subsidized imports	Energy production and agricultural development are less disadvantaged by subsidized imports compared to food	Improved storage opportunities by energy access further reduces incentive to locally produce food	Subsidised on food production from exporting countries should be eliminated.
Poorly developed infrastructure (physical, institutional, and human)	Bioenergy can be a major catalyst for development of agricultural infrastructure and formalization of the economy	Diversion of resources to bioenergy from other needed infrastructure development	Maximize local benefits - e.g. electrification, food processing, district heating & cooling
Degraded or marginal land	Perennials have potential to enhance fertility and improve soil structure and reclaim salt-affected soils New income opportunities from previously unused land	Soil and other resource exploitation and further degradation	Use perennial feedstocks Sustainable crop & crop-livestock systems Incentives for using degraded lands, with attached socio-economic conditions (to avoid displacing farmers without compensation).
Conflict & instability	Added income, markets, development, trade and stability reduce causes of conflict	Exploitive bioenergy deployment could exacerbate causes of conflict	See above

Table 1. Potential impacts of bioenergy expansion to food security dimensions

The presence of both positive negative impacts of bioenergy on each of the causative factors listed in Table 1 is consistent with the emergence of a nuanced understanding of bioenergy and food production as presented in Section 1.4.

2.4 Governance

2.4.1 Introduction

Governance refers to the collection of laws, policies, mechanisms and regulations that are used to steer social, economic and political systems. The actors involved in governing include legislatures and other public entities but also private companies and social groups. Economic governance functions through price systems established through different markets but also through various types of contracting, business or corporate rules, centrally planned production and other modes of organisation (Williamson, 1985). Good governance is critical for the management of agricultural systems and associated inputs (soils, water, nutrients, etc.) and is therefore required to ensure food security. The governance of forestry resources affects the availability of wood and other biomass for energy and thus impacts food security, indirectly in many cases, but nevertheless significant. There are a variety of institutional arrangements for effective governance of “common” resources where each individual has both rights and responsibilities in using the resource base (Ostrom, 1990). Governance for bioenergy systems has ethical implications in terms of how such rights and responsibilities are assigned and are carried out in practice (Gamborg et al, 2012).

The socio-economic interconnections among the rural poor in developing countries—where food insecurity is especially problematic—result in complex linkages between bioenergy and food security. Both the efficiency and effectiveness of governance systems must be addressed. Effectiveness is about the extent to which such systems achieve their stated goals, whereas efficiency is about improving the means of achieving those goals, i.e. the time and resources that are expended. A lack of appropriate governance systems for the management of land, water and other resources can lead to exploitation of precisely those groups that modern bioenergy is purported to help (Dauvergne and Neville, 2010). Consequently, building institutions for improved social, economic and political governance is an important element within the process of implementing modern bioenergy systems in a given community or region, as well as at the national level where key resource governance decisions are made.

The governance issues that arise at the interface between food security and modern bioenergy systems have just started to emerge since rather few least developed countries have had large-scale bioenergy programmes. In some cases the governance issues will be similar to those in the agriculture or forestry sector, although there are additional dynamics involved as energy policy issues enter the equation. Some evidence suggests that the addition of bioenergy options can in some cases force a greater level of accountability on the part of investors and resource owners compared to typical experience in the agriculture and forestry sectors (German et al, 2011). The additional scrutiny when international investors are involved and the development of international commodity markets rather than domestic markets appears to be a factor. Similarly, investment in modern bioenergy by multinational corporations--which tends to be viewed suspiciously by the non-profit sector due to potential or presumed distributional implications—can positively influence weak social and political governance structures through the empowering effects of strong economic governance in contracting and related institutional mechanisms (Purkus et al, 2012).

Community participation has been found to increase the likelihood of persistence and long-term socio-economic sustainability in bioenergy projects in forestry. This includes Community Based Forest Management, while for agriculture it may call for some type of agricultural cooperative that manages some of the physical and financial aspects of implementation. The cooperative must achieve a certain level of trust in the community and thus socio-economic and political governance are strongly linked at the local level. Where there are traditional land tenure systems, additional effort in institutional capacity is required in order to create the channels of distribution along the bioenergy supply chain.

The existence of extension programmes has proven to be important for rural transformations away from subsistence agriculture, and these extensions can usefully incorporate bioenergy add-ons, such as the use of residues for production of biogas or for small-scale gasifiers (Chapter 8). The approach used by the FAO in some countries in establishing Agricultural Business Centres (ABCs) can complement extensions by adding a business model through the creation of some basic technical capacity such as small rice mills or grinding, drying and extraction (FAO/WHO, 2013). These models serve to mobilise community-level action to improve harvesting efficiency and create a surplus. Rural development is thereby stimulated not only through the physical infrastructure but from the informal governance mechanisms for coordination of supply and demand that is created at the local level.

At the national level, governance for the agriculture and forestry sectors—as well as more general financial and infrastructure governance—can have significant implications for the linkages between bioenergy and food security. Conservation efforts in the forestry sector are sometimes designed without recognition of the resource needs of neighbouring communities. Combining conservation efforts with income-generating activities through woody biomass can reduce the extension of slash and burn agriculture and facilitate "land sharing" rather than "land sparing" although the choice between the two strategies (or even some mixture) is context-specific and depends on land tenure and related issues (Phalan et al, 2011; Edwards et al, 2014). On the agricultural side, the provision of subsidised fertilisers and other inputs has been practiced in some LDCs but faces a number of implementation problems (Chirwa and Edwards, 2013). Alternatives that address both agricultural and energy productivity could be considered instead, such as supporting the use of agricultural residues for energy production, which creates useful synergies in the value chain (Ackom et al, 2013).

2.4.2 Implementation, scale and resource ownership in relation to food security

The importance of a reliable feedstock in bioenergy systems means that the manner in which the supply chain is implemented has a significant effect on its economic viability and furthermore it also has distributional effects depending on the ownership of resources, property rights and governance systems. The scale and ownership of resources in bioenergy, agricultural and forestry management systems has some intrinsic relation to food security from the perspective of economic dependencies and risks. Table 2 provides a characterization based on the distinction between large and small-scale property rights and/or ownership of

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land, and can be applied regardless of whether bioenergy is the main product or a secondary product.

Ownership schemes		**Potential impacts on food security and/or poverty reduction**	
		Positive	**Negative**
Scheme 1:Processor by themselves/large-scale plantations		More jobs in rural areas, but duration and scale depends on degree of mechanization ; Cash injection into local economy	Difficult working conditions for rural workers The processor does not promote distribution of the generated income. For example, land prices may increase but only the operator is benefited. Displacement of more vulnerable groups (e.g. smallholders, indigenous groups)
Scheme 2: Company—smallholder partnership (contract farming)	Scheme 2.1. Large company	More secure income due to better access to markets; Reduced risk of smallholders' loss of land; support to smallholders regarding input supply and market outlets	Emphasis on bioenergy production might affect food production; Smallholders' overdependence on company for inputs and market outlets.
Scheme 2: Company—smallholder partnership (contract farming)	Scheme 2.2. Small company	More secure income through better access to markets Reduced risk of smallholders' loss of land Closer support to small-scale farmers regarding input supply and market outlets	Emphasis on bioenergy feedstock production at the expense of food crop production Smallholders' overdependence on company for inputs and market outlets Reduced efficiency in the system due to no economies of scale
Scheme 3: Smallholders/communities by themselves – small-scale decentralized schemes		Greater energy autonomy and availability at local level. Better processing potential for agricultural products and other local products Health improvement if from traditional fuelwood to cleaner cooking energy Enhancement of education level due to enhanced lighting	Unfair competition for land for food and bioenergy production (but likely to be limited)

Table 2: **Implications of alternative bioenergy schemes for Food Security/Poverty Reduction** *SOURCE: adapted from FAO/UNEP 2011*

Professionally managed large-scale options may carry lower economic risks but may yield fewer benefits for the community; some benefits can be maintained if production is organised in favour of smallholders. One can distinguish three types (and two sub-types) of ownership relations between suppliers and purchasers of biomass:

- Scheme 1: One company or operating entity receives and processes biomass grown on large-scale plantations owned by the company or operating entity (vertical integration of agricultural/forestry and industrial sides of bioenergy production).
- Scheme 2: A partnership is established between a company or entity and smallholders; normally this constitutes some type of contract farming in which land is purchased (or inherited) or leased (Bijman, 2008). This scheme should be distinguished by two types, based on large-scale vs. small-scale production or company size.
- Scheme 3: The community-based small farmers are organised into a decentralized scheme whereby biomass feedstock is used in smaller-scale production, often coupled to local small-scale conversion options such as generators for off-grid power.

Schemes 1 and 2.1 have potentially large scale impacts with likely more will and capacity to comply with sustainability standards and regulations especially transnational. This scheme is also more related to export and national markets. Schemes 2.2 and 3 have potentially smaller-scale impacts if overall small scheme and local markets are involved.

It should also be noted that as agricultural and bioenergy markets develop and mature and demand for both food and energy increases, there will tend to be migration to Schemes 1 and 2 and away from 3, although this will differ somewhat depending on the underlying scale economics of the particular feedstock or crop and application.

Small-scale schemes can often have significant potential to promote rural development, especially when using locally-produced feedstock, through proximity to energy production, job creation, income diversification, and increased local capital accumulation (PAC, 2009). Coordination at the national level can support rural development initiatives, such as the case with Thailand’s ethanol program in which cassava from small farmers serves as a feedstock in addition to molasses/sugarcane (Chapter 7: Case Studies). Some of these schemes are not mutually exclusive. In fact, in the case of sugar cane and some other crops, it is common in many African countries that a company operates a large estate but also has agreements with smallholders accounting for perhaps 20% of total production. The company provides technical support and equipment, and the farmers agree to provide a certain quantity and quality of feedstock. Reliance on smallholders saves administration costs for the company, improves the flexibility of feedstock supply through diversification and also maintains good public relations with the community through socio-economic benefits and infrastructure (Johnson et al, 2007).

It is worth bearing in mind that smallholders can be key partners and investors (through labor and resources) in bioenergy development even when technical and financial conditions require large-scale processing. The relation between investment and resource ownership can also be assessed on the basis of the risks and rewards to different actors and how they vary as the institutional arrangements change (Vermeulen and Cotula, 2010). The effects of small vs. large-scale schemes nevertheless tend to be quite different; large-scale schemes tend to be less connected to the community needs as they are focused on international or regional markets, creating concrete economic benefits but entailing social and environmental risks. When community members are engaged in the whole bioenergy chain (i.e. growing the feedstock, establishing conversion systems, choosing final markets and products) there are better opportunities to internalise socio-economic impacts. With good governance systems, the costs and benefits are more likely to be fairly distributed, even when large firms are involved. Some communities may nevertheless prefer the higher certainty and tangible cash benefits of working through a larger entity or company, and this choice should be left up to the community when it comes to specific investments or projects. In summary, the impacts of bioenergy production do indeed differ across scales, while the costs and benefits of those impacts and the resulting risks will be borne by different groups depending on land tenure and resource governance systems.

3 Conclusions

- On a global scale enough food and energy are currently produced, so that hunger and malnutrition are primarily problems of access and/or distribution along with the income levels of the poor
- There is enough land available to produce the required food demand for the foreseeable future and to produce a considerable fraction of energy demand through bioenergy
- Some care must be taken to avoid reliance on staple food crops and to avoid excessive reliance on productive agricultural lands for bioenergy by promoting the use of degraded lands, expanding co-products, practicing integrated land use management, and promoting advanced biofuels that use many types of biomass as feedstock
- Bioenergy can improve food safety; food production systems and reduce or re-use wastes
- Bioenergy can improve supply chain / infrastructure for food products
- Bioenergy can stimulate investments in agricultural production improving yields and create long term stability
- Bioenergy infrastructure can provide a dynamic and flexible production system, in which farmers and suppliers can switch between energy, food and other bio-based products as needed
- Bioenergy can provide better access to foods as Bioenergy provides jobs, which increases food security by higher income, education and improved infrastructure
- In order to achieve these identified benefits, good governance and supporting policies are crucial, both at local scales as well as at national and global levels

Reliable energy access is generally a precondition for improved food security, and independent of the origin of the energy, increased energy availability will help to reduce poverty and improve food security (Chapter 14). If bioenergy can help improve food security, it makes sense prudentially for all parties to support bioenergy development.

Food security is predominantly related to access to food, which is impacted by poverty, conflict and availability. For rural areas, biomass utilisation for bioenergy can negatively impact availability, but positively impact economy (jobs, increased income, investment and improved infrastructure) and food quality (better preservation and preparation options through availability of energy). For urban communities, availability is not so much an issue, but higher food prices due to more competition of feedstocks, could negatively influence access and increase food insecurity. So far, the effect of bioenergy production to food prices however has been shown to be relatively small. Therefore, there is no clear causal relation between bioenergy/biofuels and food insecurity; it can be neutral or impact positively or negatively and needs good management systems and governance to support (economic) development, poverty reduction and food security.

From the recent evidence collected in this report we can conclude that bioenergy can be implemented in ways that have neutral or positive impacts on food production and security. If done right, production of bioenergy contributes to

- decreased price volatility of grain crops, resulting from a diversification of revenue sources from agricultural produce, reducing risks and increasing income
- agricultural infrastructure development by investments for biomass production for bioenergy
- rural economic development, supported by local energy availability and development of chains, market structure and infrastructure
- providing a flexible switch system (use of biomass for food or energy) in times of abundance and of scarcity

The question then can be asked, is there enough land available to sustainably produce food, feed and biomass for energy for a growing population? As specified in chapter 1 it is concluded that there is ***enough land available*** for substantial bioenergy production and increased food demand, considering impacts of global change affecting crop production, yield increase predictions, and preservation for urban areas, forestry and protected land.

Three elements of global change that affect food crop production and interact with bioenergy are taken into account: 1) Climate change may cause a small decline in yields by temperature changes and extreme events; 2) changes in atmosphere, the tropospheric ozone may reduce yields but rising CO2 may increase yields (effects will be mixed); and 3) land degradation, where bioenergy production can help to recover land for food production that became degraded. Overall we conclude that there is an increased yield potential at higher latitudes but reduced yields and food production in semi-arid tropics. Also the projected rate of increase in global demand for food and feedstuffs of around 2.4% per year was assessed against the yield improvements in main food crops (maize, rice, wheat, and soybean). Some project that due to anticipated low rates in yield improvements demand will outstrip production by 30% over the coming 35 years, requiring an additional 130 - 219 Mha of agricultural land. Even if pessimistic projections are true, this should not be a problem as land availability for rain-fed agriculture is estimated to be 1,4 Bha (excluding land already in use for agriculture, forests and protected land). This land is strongly concentrated in Latin America and Sub-Sahara Africa (almost half of the available 1,4 Bha), and presently used predominately for low intensity grazing. Developed countries also have land available but the agricultural area is expected to remain stable**.** In addition there is about 607 Mha of farm land available that has become degraded. Not only can degraded and marginal land be used for bioenergy feedstock production, but in doing so, the land can be rehabilitated and improved, providing a positive impact on soil quality, productivity and again on food security. In conclusion, at a global level, land is not a constraint but availability is expected to be concentrated in two main regions.

In considering the impacts of bioenergy to food security we found many positive examples of local benefits from bioenergy production. However, it is important to be aware of negative impacts, and to know how much these affect food security and how they can be avoided. For example, land grabbing as detailed by Cotula et al (2008) (acquisition of large tracts of arable land by foreign countries or multinational corporations for export markets) may offer no food security benefits and could even exacerbate food insecurity. The data we investigated, however, show that only 0,5% of land deals in recent years were related to bioenergy production (Hamelinck, 2013). We emphasise that good governance is an important factor to ensure that positive impacts of bioenergy are achieved. In terms of implementation, policy measures and investment in research, piloting and business development will be required, but attention must also be given to technical support for farmers, land tenure schemes and development of cooperatives. In countries with weak political structures, (foreign) investment can promote agro-industrial development, which in turn, could enhance food security; financial and environmental scrutiny is increased when international investors are involved, while at the same time local entrepreneurs are empowered through market discipline. More examples on how local, national and global policy measures and infrastructural measures impact food security should become more widely communicated to both increase our learning on beneficial implementation of bioenergy as well as to ensure that wrongly based assumptions negatively impact public (political) opinion.

In defining strategic policies and investment schemes it is important to realise that bioenergy is inextricably connected with ethical questions, particularly the responsibility to manage risks of food insecurity and climate change in ways that take into account persons who are underrepresented because they are poor or unable to look after themselves. This includes looking after future generations, implying that we have an ethical obligation to try to prevent the damaging effects of climate change. In the case of food insecurity, some NGOs have opposed the production of bioenergy using arguments based on (global) land availability and (expected increased) food prices. We have shown that these arguments based on global land availability are *not founded* by the fact that there is enough land available and also by the fact that 60-70% of people with food insecurity live in rural areas, where energy poverty is also common. Here bioenergy can increase food security as increased food prices would increase income for farmers and that together with increased energy security rural economies will be boosted.

Much research has been done in the last 5 years to investigate the assumptions behind assessments on bioenergy and food security. We now have much better insight in the availability of land and the development of food prices. As land availability is not expected to be an issue and food prices are not expected to be too much impacted by bioenergy production, we have the duty to consider ways in which bioenergy production can improve food security. Although the impact of bioenergy on food security must always be taken into account, it need not create obstacles to introducing bioenergy where its impact on food security is neutral or positive. Moreover, the status quo of areas with food insecurity that also lack energy access is not acceptable, since such conditions often involve a cycle of negative environmental impacts with little or no economic return, such as the traditional, unhealthy practices of the use of wood or dung for cooking. The responsibility to look after the food-insecure poor is the responsibility of society at large, and not solely the responsibility of the agricultural or food-producing sector, the latter being the case when there is an overemphasis on keeping food prices low. It is prudent to help those affected to acquire the means to solve their food and income problems through their own agency, which is the basic idea behind stimulating development that benefits rural communities. Bioenergy has a clear potential to achieve this goal and should be considered as a viable option for policy measures and investment schemes.

4 Highlights

- There is enough land available for substantial production of bioenergy and food for a growing world population, expansion will be predominantly in Sub Saharan Africa and Latin America
- There is no inherent causal relation between bioenergy production and food insecurity
- Bioenergy can improve food production systems and rural economic development, but requires good governance
- Bioenergy can stimulate investments in agricultural production in poor areas and provide a dynamic switch system to produce energy ***or*** food whenever necessary
- It is our ethical duty to develop and evaluate practices of combined bioenergy and food production in poor areas

5 Recommendations for research, capacity building, communication and policy making

Research recommendations

- We need critical empirical studies that will identify the key success factors and generate the general and specifically context related conditions for positive impacts of bioenergy on food security.
- Research is needed to clarify the impact of bioenergy production on rural food security and urban food security and account and monitor to create insight in positive and adverse, transient effects of bioenergy developments. This also requires the development of improved governance, and monitoring of sustainability and social benefit indicators, likely based in part on (spatially) explicit information systems. This information must be available and usable for local populations and decision makers.
- We need a robust research and extension system focused on constant improvement in farming practices, including the impacts of different scales of operation. Research on effective management of land with a focus on yields and sustainable practices should inform agriculture worldwide and include the development of markets for agricultural products.
- We need to continue to try to understand and predict where possible the food security impacts of specific regulations, policy measures and institutional arrangements (such as cooperatives for small-scale production) in relation to bioenergy and agricultural systems.
- Financial and knowledge investment in sustainable agriculture for biomass production for food and energy is crucial to increase food security. This requires insight in best practice models of investment in both innovation and finances (such as the role public private partnerships can play to achieve both economic and social benefits). Essential is the support or creation of adequately funded agricultural research and extension systems capable of supporting sustainable agricultural intensification in each locale.
- The estimates on land availability for food, feed and energy production vary and are uncertain due to uncertain predictions about local and regional consequences of climate change generally, and effects on yields particularly. Ground truthing of satellite imagery and government land use data is crucial, particularly in poor regions to improve data on actual land use patterns. Such data will support factual assessment by regulatory bodies of consequences and opportunities for complimentary developments of further bioenergy and food production.
- Retrospective analysis of "what would have happened without bioenergy?", particularly with respect to food security, agricultural development, and social benefits in Brazil and the US to understand the impacts of bioenergy on food security.

Capacity building recommendations

- Activities and funds should be organised to ensure capacity building on the use of good practices in (mixed) bioenergy production and food security achievement through education and communication, with a focus to local and regional actors. Essential is the support or creation of adequately funded agricultural research and extension systems capable of supporting sustainable agricultural intensification in each locale.
- Agri-business development training in rural areas through entrepreneurial extensions (in addition to agricultural extensions) can help farmers to access markets for food and energy crops or products, as well as for improving supply chains and distribution channels.
- Investment in the skills and other manpower development needs for (local) bioenergy production (including on technology, governance, management and effect on food security) should be facilitated by governments.
- Training in business skills and community-based participatory processes would help to better prepare rural residents for foreign investors, so that they can maximise the benefits for food security as well as energy provision. This has to be done after business starts to develop with due attention for local conditions as they suggest appropriate solutions.

Communication recommendations

- The global food versus fuel debate is dominated by misinformation, causing policy makers to hesitate implementing policies to stimulate bioenergy production when it could benefit food security. Communication and engagement between stakeholders should be improved and scientists should be involved to ensure better informed debate and better informed policies to increase the mutual learning process. This requires research on effective methods of communication, taking into account the role of trust, normative viewpoints and cultural practices.
- Scientific data, defining best practices (technology, sustainability and social and economic impact), should become available in understandable formats for local and regional actors, including farmers and companies producing bioenergy. This can be developed through national and regional research and extension programs.
- Assembled data, such as in this report, should become readily available for policy making and governance. Efforts should be made to engage key policy makers in discussing the conclusions presented and recommendations in workshops and/or conferences to optimise the delivery of the main conclusions and ensure a proper perception of the data.
- Investment should be made into better communication between stakeholders in the novel chains of multi-scale agriculture, producing bioenergy and food. In countries like the US, this is the role of cooperative extension programs though other models are possible. They need to collaborate to improve social welfare, food security, and other elements of sustainability.

- Many development programs for improved agriculture presently do not consider the integration of bioenergy production. Meetings between bioenergy experts and aid supporters (such as the FAO, Oxfam, etc.) should be organised to inform these programs on positive impacts of bioenergy and how this could be realised.

Policy recommendations

- Promising novel developments in bioenergy production that improve food security need to be rewarded and stimulated through policy measures that encourage and reward local entrepreneurial developments. Governments should stimulate bioenergy innovation by supporting research and pilot-scale developments, based on well-considered indicators that are meaningful for specific local contexts.
- Local and national governments should identify and solve conflicting regulation (e.g. across policies in agriculture, forestry, energy, transport and environment) for those innovations in bioenergy that promise a positive impact on food security.
- To create a level playing field and reward innovation and capture all possible GHG savings, biomass energy projects should be judged on their ability to reduce GHG's, while also satisfying other community needs (sustainability and food security). California's Low Carbon Fuel Standard is a one possible model for such a program.
- There is a need for governments and international agencies to support objective trials, evaluating social benefits, economics and food security to poor communities in such areas to inform farmers and international communities on the options and viability of utilisation of these lands.
- Improving the investment climate is crucial and needs strict control and governance to improve the stability dimension of food security. Low yields and high initial input costs may put off potential investors in bioenergy feedstock production on degraded and marginal lands. Therefore we need low interest start up loans, tax relief and discounts on the transport and distribution of the produce. The policies need to ensure that biomass production for bioenergy benefits rural communities. Farmer organisations may play an important role in this. In addition land tenure rules need to be in place to ensure that rural communities continue to have access to land for their livelihoods.

6 Tables and figures

Presently in text.

7 Press Release

Logo and heading to be decided in collaboration with SCOPE

Date (embargo if required)

"Bioenergy can help to improve food security and where this is the case, bioenergy researchers and practitioners have an ethical obligation to support bioenergy expansion to help those who are affected by food insecurity" conclude eleven scientists from six countries. These scientists were invited by the Scientific Committee of Problems of the Environment (SCOPE) to evaluate the recent evidence on the effects of bioenergy production on food security as part of the new Bioenergy report. The group concludes that there is enough suitable land available to accommodate both increased food demands and a considerable contribution to energy production. Moreover, they found growing evidence that bioenergy production in poor rural areas can help improve economic growth, job security, market development, food quality and food security. They do warn however that adequate governance schemes need to be in place to ensure that sustainability is achieved and that the benefits are distributed equally. Better understanding of the impacts of regional, national and global policy measures, regulations and certification systems needs to underpin such governance schemes. Also financial investment schemes need to be considered carefully to maximally profit from the integral production of bioenergy. The findings contradict the inappropriate generalisations that are common in the present food – fuel debate. "This is mainly due to recent evidence of actual case studies that have shown such positive impacts. The assumptions held by those who are against biofuels are based on predictions rather than on facts, or on misunderstanding of causal relations and food insecurity problems" says Patricia Osseweijer, lead author of this chapter. " it is important that we continue to study and monitor effects so that we can learn together how to maximally benefit from sustainable agricultural practices". "we also need to ensure that these findings are well communicated, to prevent negative effects of ill adapted policies".

The full report can be found at ….

Contact: To be decided in collaboration with SCOPE

Background info SCOPE

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Lee Lynd, Stephen Kaffka, Stephen Long, Hans van Meijl, Andre Nassar, Jeremy Woods

8 The much needed science

Integrative approaches addressing bioenergy and food security are essential. If there is a consensus about the importance of alternatives to fossil fuels and the necessary increase in food security from the local to the global scale, efforts must be made to conciliate these two demands. These efforts should be science based and hence require further scientific research in the following fields.

1. Farming practice and management in relation to food security

Integrating bioenergy production in food production systems in ways that increase food security requires knowledge of key success factors. Empirical studies are needed that will identify these and that will generate the general and specific context related conditions for positive impacts of integral systems. This necessitates multidisciplinary studies in which agronomics, economics and management studies, bioprocess engineering and social studies provide input to fully understand the value chains in specific regions. Studies will have to identify improved yields, and better water and nutrient management while generating insight on the required scale of operations for bioenergy production which will increase sustainability of agriculture in general. This also includes studies into the use of degraded pasture lands that have been recognized as an available option for bioenergy production. Thus, research on the potential of pasture intensification, including particular strategies to maximize sustainability benefits should be carried out. Currently lands that were previously used for food and/or cash crop production and are currently abandoned and those that are only marginally suitable or unsuitable for food and/or cash crop production should also be evaluated for the same purpose. International collaboration with developing countries can address agricultural research and food security directly by drawing on common experiences, such as the case with Brazil and Mozambique (Box 3).

2. Food security indicators and monitoring

Bioenergy is only one of the many aspects that can affect food security. Validated monitor systems of food security need to be developed that can be used to assess the possible impact of bioenergy. This requires insight in the relative effects of all factors including local infrastructure (transport, grid availability, water availability, industry infrastructure, etc), employment levels, availability of education, economic opportunities, market structures, etc. Data need to be assembled and interpreted and linked to specific contexts. In additions to quantitative data this also requires the evaluation and incorporation of qualitative factors. Novel methods for cheap and easy monitoring need to be developed on the basis of insights of relative impacts, which could be incorporated in sustainability schemes. This will provide steering knowledge for policy incentives and investment requirements and will increase our understanding of differences between specific rural and specific urban food insecurity and how bioenergy can impact these. Again this will necessitate the collaboration of different disciplines, including e.g. social sciences, socio-economic modelling, and market studies.

3. Governance including regulations, local and global policies and certification

Governance has been identified as a key factor to achieve positive effects of bioenergy production on food security. However, our knowledge on how local, regional and global measures, regulations and certification schemes impact rural practices and food security is very limited. There is an immediate need for empirical studies which evaluate these effects on a local scale and translate that knowledge to better governance practices. This includes specific knowledge on institutional arrangements (including for example cooperations) and how local or regional communities are likely to embrace these. For the latter we also need to understand community values on technology utilisation and governance structures. The interplay between local, regional, national and global schemes needs to be evaluated for different situations, so we increase our understanding of conflicting systems and adverse impacts. Input is required from science policy, international relations studies, market studies and management studies, with understanding of impacts in agriculture for bioenergy, feed and food production.

4. Finance and investment models

In addition to governance we also require insight in financing models for improved sustainable agriculture. Investment in bioenergy production could be made in many ways, and has likely different impacts in different local situations. Understanding the key relations for specific schemes to specific contexts is crucial. Data on best practices should increase our insight on improved schemes for financing as well as on the way how this should be governed or organised. Knowledge on requirements for small and large scale bioenergy production from bioprocess design should be combined with knowledge on innovation management and financial management.

5. Communication and mutual learning

Integration of disciplinary knowledge highly depends on ability of mutual learning and effective communication. In deploying bioenergy for improved food security we deal with many stakeholders and experts who have not collaborated before. This requires communication which provides the validated scientific facts and which is trusted by all parties. Trust is a precondition for learning and can be improved by transparency and mutual engagement (to listen and respond). Novel ways of communication need to be designed that take these factors into account and can increase the learning curve. In addition, communication of factual data on how bioenergy can improve food security to public(s) in general should be designed in such a way that it takes the negative and wrong assumptions away and decrease the negative impact of public opinion to policy and decision makers. This requires input from communication sciences and ethics.

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Box 1 : Sugarcane ethanol and Brazilian Agricultural Development

Brazil is an example on how a country can increase its bioenergy production while increasing its food security. In fact the expansion of the agricultural production and yields in Brazil were partially derived from a better production environment in the rural sector, related to agronomic practices, availability of services and equipment and adoption of modern technology partially derived from the sugarcane sugar & ethanol sector.

This effect was not in sight when the fuel ethanol production was reinforced in Brazil. The basic driver to implement a large sugarcane ethanol program in Brazil in 1975 was to reduce the high energy dependence and the heavy economic burden resulting from oil imports (80% of domestic consumption). The 1st oil shock in 1973 made Brazilian oil imports corresponded to nearly 50% of all its imports creating a huge structural problem for the economy. Currently, sugarcane responds with17.5% of Brazilian primary energy supply (MME, 2013).

The learning process verified by sugarcane ethanol in Brazil notably in the 1975-2008 period (Goldemberg et al (2008)), was in great measure due to the gains obtained in improving sugarcane agriculture. These gains were mainly derived from the introduction of new sugarcane varieties, better agricultural practices (such as vinasse and filter mud recycle), and good management. From 1975 to 2008 sugarcane yield grew fro 46.8 to 77.5 tons/ha.year resulting in an ethanol cost decrease from US$ 1.20 to 0.38/liter (Lago et al., 2010).

Until the beginning of 70's Brazil was fundamentally an exporter of coffee. Due to many factors, including synergies with the sugarcane ethanol program, the country became a large exporter of agricultural commodities, including grains (soybean, corn), meat (beef, poultry, and pork), pulp and paper, orange juice while maintaining its leadership in coffee exports. Examples of synergies can be the development of more detailed soil maps, improvement of logistics, agricultural machinery, besides more qualified management skills in Brazilian agriculture.

The grain sector (CONAB): in 1977/78 harvested soybean was 9.7 Mt, corn was 14.0 Mt, and total grains was 38.2 Mt ; in 2012/13 harvested soybean was 81.5 Mt, corn was 81.0 Mt, and total grains are expected to be 196.6 Mt in 2013/14. Therefore, in the same period of analysis, while soybean production grew 740%, its planted area grew 272%, and corn production grew 478% and the planted area grew 39%, showing an important gain in productivity (especially due to the use of second crop), implying that a significant amount of land was saved due to productivity gains.

The meat sector (CONAB/SUGOF/GEOLE and MAPA, 2013): the same trend was observed. In 2006 poultry production was 9.35 Mt, beef production was 10.18 Mt, pork 2.94 Mt, and fish 1.05 Mt, with 23.52 Mt of total meat In 2013 poultry production was 13.27 Mt, beef production was 8.92 Mt, pork 3.55 Mt, and fish 1.2 Mt, with 26.94 Mt of total meat. During the course of the last decades Brazil became the world largest exporter of meat (beef, poultry and pork).

All together, according to SECEX/ABAG (2013), the Brazilian agribusiness sector is responsible today for nearly US$ 100 billion in 2013 (nearly 40% of overall exports) helping the country to obtain positive surpluses in the recent years. .According to IBGE, total planted are in Brazil is 63,6 Mha (around 7,5 % of total area). The main crops in Brazil are soybean (24,9 Mha) and corn (14,2 Mha). Sugarcane is the third crop occupying a relatively small area in Brazil, around 9.4 million ha or 1.1% of Brazil total area, being nearly half for ethanol and the other half for sugar. It can be stated that Brazil became the largest exporter of sugar in the world mainly by the existing synergies between ethanol and sugar production. The sugarcane sector in Brazil also contributes directly to the production of grains, mainly peanuts and soybeans cultivated in the sugarcane reforming areas. (BNDES/CGEE, 2008).

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Box 2: Effects of *Jatropha curcus* on food security in Africa

Indigenous to central-south America, Jatropha was introduced to Africa a few centuries ago Very suitable and suitable areas for the plant respectively cover 1.080 Mha and 580 Mha of the continent, Parsons (2005). It is currently widely distributed throughout these areas where rural inhabitants generally make extensive use of it. Because it is unpalatable to livestock, it is predominately planted in rows around crops, and as wind and soil erosion barriers (Boccanfuso *et al*., 2013). These 'living fences' enable the time saved seeking suitable wood to make and maintain fences, to be spent tending crops.

A wide range of products are made from Jatropha bark, leaves and different parts of the fruit (Oppenshaw, 2000; Parsons, 2005). Oil from the seeds is used as a diesel substitute or blend in vehicles, pumps and generators; as a kerosene substitute in lamps; for making candles, etc. 'Press-cake'- the by-product from extracting oil from the hulls, and the shells are made into briquettes, used to generate biogas and/or applied as organic manure to cultivated areas. Mkoma and Mabiki (2012) reveal that the press cake is an excellent fertilizer. Money 'saved' from not having to buy, and made from selling Jatropha for bioenergy, household, medicinal and agricultural by-products, improves food security.

Since the new millennium, NGOs and private companies have actively encouraged Africans to plant more Jatropha hedges and to intercrop with it, as a rural development strategy. The strategy involves encouraging communities to form cooperatives to manage their own bioenergy and fertilizer provision. The NGOs variously (a) provide oil extraction machinery, electricity generators, alternators, milling machines and battery chargers, (b) help construct a mini-grid to distribute the electricity to the cooperatives' roads, households and water pumps, (c) distribute seeds/seedlings and (d) train people how to maintain the machines/ infrastructure, manage members to ensure a regular supply of Jatropha seeds, and derive an income from other Jatropha by-products. PAC (2009) and Boccanfuso *et al*., (2013) examined the Garolo Cooperative in Mali, and Angstreich and Jackson (2007) and Sawe (2013) examined many similar cooperatives in Tanzania facilitated by TaTEDO. They all concluded that Jatropha bioenergy (and by-products) derived, distributed and used in this manner would enhance food security.

Several companies (with or without land holdings) have successfully contracted independent small scale Jatropha farmers to supply them with seeds which are variously used to produce oil for blending with diesel and paraffin, fertilizer and briquettes. Research by Mitchell (2008), Gordon-Maclean *et al*., (2009), van Eijck (2009) and Sawe (2013) on farmers contracted to Diligent in Tanzania and by BERL (2013) on farmers contracted to them in Malawi, have shown that the income derived from selling seeds enhances their food security. It must be noted, however, that large-scale markets for seeds are often dependent on government policies for using jatropha oil in the transport sector; if these policies are inconsistent or undeveloped, the market for seeds may disappear and disadvantage small-scale farmers that invested in jatropha (German et al, 2011).

Other companies acquired land for large scale commercial Jatropha plantations intent on producing biodiesel for national and export use. Plantation-style jatropha has proven to be very difficult to make into a commercial crop, which is perhaps not surprising when considering the relatively short period of domestication thus far (van Eijk et al, 2012; von Maltitz et al, 2014). Nevertheless, as of 2008, plantations accounted for 11% of Africa's Jatropha production (Boccanfuso *et al*., (2013). However, this proportion is unlikely to increase because a number of factors coincided to arrest this process. Most African countries now have bioenergy policies in place that ensure such ventures will not take place on arable land or threaten food security in future.

Box 3 : Parallels – Bridging cooperation in both ways

Understanding the arrangements established between the historically produced biophysical and human factors allows the identification of regional patterns and processes, an essential knowledge for the management of natural resources and agriculture. The Brazil-Mozambique cooperation, which is based on the parallelism among geographical situations and prospects for development, falls within this context of latitudes, culture, and agriculture (Batistella and Bolfe, 2010).

The cooperation between the Brazilian Agricultural Research Corporation (EMBRAPA) and the Agricultural Research Institute of Mozambique (IIAM) includes land management systems, soil surveys, land-use and land-cover mapping, agroecological zoning, environmental impact assessments, productive process improvements, agricultural intensification and land degradation monitoring, among others.

There exists several development opportunities for the Mozambican agriculture and bioenergy production based on the knowledge generated in Brazil. The Brazilian experience in cerrado areas represents an important differential for the development of tropical agriculture, now enriched with the need to minimize environmental impacts. More than just exporting technologies, there is the willing to learn how to build together a virtuous future integrating mutual experiences and common goals, i.e. interdisciplinary actions for development and cooperation, based on the promotion of agricultural intensification, implementation of good practices, and on cautious indications for the expansion of the agricultural frontier.

The ties that unite Brazil and the African continent surpass historic links, cultural heritage, behaviors, and traditions. They strengthen themselves in actions that promote social and economic integration, especially for agricultural and regional development.

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Box 4: Food and Energy competition for Crude Palm Oil in Thailand

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Thailand has increased the share of alternative and renewable energy from 0.5% of final energy in 2005 to 11% in 2013 (www.dede.go.th); the ten-year National Alternative Energy Development Plan (AEDP 2012-2021) now aims to increase that share to 25% by 2021 (DEDE, 2012). Targets of 9 and 7.2 million litres per day of ethanol and biodiesel have been established for ethanol and biodiesel, respectively. Competition between food and energy arose for crude palm oil (CPO); its use for B5 blends resulted in a price increase of over 30% in 2011. There were shortages of cooking oil, its price rose by over 50% and household purchase was rationed. Corrective measures were applied to restore the balance between domestic and transport demand, including international trade with Malaysia, flexibility in the blending ratio and maintaining buffer stocks. There has also been some concern about the effects of the oil palm expansion on the indigenous rice cultivation, and only a small project has been done to evaluate such effects and determine how they can be mitigated. An agricultural zoning policy has also been launched to address productivity issues and ecological impacts related to palm oil and other crops.

BOX 5: Food security has been helped by maize use for ethanol in the US

Having major food and feed crops produced in diverse regions of the world helps increase food security by buffering the risk of adverse weather and other events on the stability of supply. Increasing the value of major crops leads to temporary increases in price, but also greater investment in technology and infrastructure. In response, depending on demand, prices decline as investments and development increase supply. The decision of the US Congress (2004, 2007) to mandate the use of ethanol in transportation fuels in the US increased domestic demand. for maize, often produced in large surpluses. Approximately 40% of the US maize crop is used now for this purpose. In turn, this newly significant demand influenced the rise in the price of maize. Other factors influencing price simultaneously were increases in the price of oil relative to maize, and rising demand for soybeans from China produced from the same land (HLPE,2013). In response, over the period 2007 to 2013, approximately 4 M ha additional land was planted to maize in the US, diverted from other crops. and acres released from land reserves. Maize price rose during this same period. In 2012, an exceptional drought occurred in the primary US maize growing region and average expected yields fell by approximately 30%. Since the US is the major exporter of maize, this was an important event, potentially, for food security. As US domestic demand for maize increased, adjustments were occurring elsewhere. Maize production expanded modestly in areas of the US outside the upper Midwest, to areas less affected by drought. More importantly, maize production and exports increased during this same period from Argentina and Brazil and the Black Sea region, reducing the world-wide effects of the US drought on supply. Additional supplies from these regions, as in the US, were met by increased productivity (double cropping in Brazil, yield increases in the Black Sea region and the US) and some area expansion. Expanded capacity for maize arguably leads to similar improvements in other commodities, and in generally beneficial infrastructure development, for example in grain handling and logistics, and agricultural intensification. This increases stability of the food system against perturbations from local weather events and longer-term climate change, local policy changes or disruptions, access and availability of food, and prosperity in rural areas producing more crops throughout the world. (Tyner , 2013; Taheripour et al. , 2013). This positive view of crop use for biofuels depends on prudent policies which also encourage other feedstock sources, and reasonable limits on maize use. GHG limits on biofuel emissions arguably act to limit maize use, but limits to mandates do as well. In the US, long-term surplus supplies were absorbed by ethanol production with positive regional and national effects, and productivity increases and shifts in meat consumption patterns from beef towards poultry and pork (both domestically and internationally) have contributed to supply during the ethanol expansion period.