**Literature Review of the**

**Nexus between Bioenergy and Nutrition**

**Acknowledgements**

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**Table of Contents**

Introduction ……………………………………………………………………… ……….2

Part I: Peer-Reviewed Literature ………………………………………………………… .3

Part II: Case Studies………………………………………………………………… …….9

Part III: Potential Policy Implications……………………………………………………..12

Part IV: Use of preliminary Findings…………………………………………………… 14

**Introduction**

Bioenergy and nutrition links have tended to focus on the potentially negative impacts of the production of conventional biofuels on human health and nutrition, through increased GHG emissions, direct effects on health and sanitation, and reduced food availability and associated price effect as well as further environmental impacts, such as deforestation, and erosion and loss of biodiversity. This literature review acknowledges the controversial nature of this topic but recognizes that the interactions between bioenergy and nutrition are complex and specific contextual problems and opportunities need to be taken into consideration.

The aim of this literature review was to collect and analyze the available evidence most relevant to the relationship between bioenergy and nutrition. The literature review was exploratory rather than systemic in nature, and primarily involved internet searches for peer-reviewed literature and government/intergovernmental documents on this topic.

The literature review explores the various interlinkages between bioenergy and nutrition, including implications on food security and nutrition security as well as the impacts on the agricultural and transportation sectors. The literature is broken up into four sections: i) peer reviewed journal articles, ii) case studies, iii) potential policy implications, and iv) distribution of findings. A summary of the main findings is presented at the beginning of each section. Papers in each section are organized by the published year.

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| Key concepts:   * **Food security** is a situation that exists “when all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life”. Based on this definition, four food security dimensions can be identified: food availability, economic and physical access to food, food utilization, and stability over time. The SOFI 2021 includes the dimension of “sustainability” to food security which refers to the long-term ability of food systems to provide food security and nutrition in a way that does not compromise the economic, social, and environmental bases that generate food security and nutrition for future generations * **Nutrition security** is a situation that exists when secure access to an appropriate nutritious diet is coupled with a sanitary environment and adequate health services and care, to ensure a healthy and active life for all household members. Nutrition security differs from food security in that it also considers aspects of adequate caregiving practices, health, and hygiene, in addition to dietary adequacy (SOFI 2019). * **Food and nutrition security** is commonly used in the policy language with reference to availability, access, utilization, and stability of food. There is not a commonly agreed UN definition of food and nutrition security. * **Diet quality** is comprised of four key aspects: variety and/or diversity, adequacy, moderation, and overall balance. Exposure to food safety hazard is another important quality aspect (SOFI 2021). |

**Part I: Peer-Reviewed Literature**

*Questions to Address:*

* *What are the links between bioenergy and nutrition security?*
* *What is the evidence?*

**Summary of Part I Findings**

* Food versus fuel discussion remains controversial
* Links between bioenergy and nutrition security are **indirect**

Strongest links are:

* Biochar and digestate can be applied to crops as fertilizer, reducing the need for chemical fertilizers and improving soil quality
* Bioenergy and its byproducts can be used as components of climate-smart agriculture systems that integrate techniques and practices such as intercropping, use of crop residues, etc., which could lead to improved nutritional outcomes/nutrition security, although further studies would be needed to corroborate this link.
* Expansion of sustainable bioenergy to diversify livelihoods, leading to improved income and diets, taking into account context-specific opportunities and minimizing potential risks.
* Use of bioenergy for transportation may improve transportation efficiency, allowing rural and developing regions to gain better access to more diverse food baskets

**Tirado, M.C., Cohen, M.J., Aberman, N., & Thompson, B.** 2010. Addressing the challenges of climate change and biofuel production for food and nutrition security. *Food Research International*, 43. <https://doi.org/10.1016/j.foodres.2010.03.010>

The authors of this paper explore the intersection between climate change, biofuel production, and food and nutrition security[[1]](#footnote-1), noting that all three are inexplicably linked. The pathways through which climate change may impact food and nutrition security are complex, and consist of biological, ecological, and socioeconomic systems, all of which are also impacted by climate change. Some of these pathways include increased frequency of extreme climatic events such as droughts, flooding, tropical storms, and heat waves, sea-level rise and flooding of coastal areas, leading to salination of water and agricultural lands and food, and impacts of temperature increase and water scarcity on plant physiology. Regions likely to be adversely impacted by these changes are those that are already vulnerable to food insecurity and malnutrition, such as Sub-Saharan Africa, South Asia, and small island developing states. Populations at the greatest risk of malnutrition include smallholder and subsistence farmers, pastoralists, indigenous and traditional societies, and artisanal fisherfolk, all of whom will suffer from complex, localized impacts of climate change. Rising global prices of oil and gas, as well as fossil fuel impacts on the climate system have made alternative energy sources such as biofuels, an attractive option. Biofuel production can have significant impacts on food security. One major problem is the diversion of food crops to biofuel production. Returns from production of biofuels are often greater than the returns a farmer may see from the sale of the same crops for food. Such practices may consign food production to less productive land, reducing yield and food security in the process.

**Bogdanski, A.** 2012. Integrated food-energy systems for climate-smart agriculture. *Agriculture & Food Security,* 1(9). [Cited 17 November 2021]. <https://agricultureandfoodsecurity.biomedcentral.com/articles/10.1186/2048-7010-1-9#citeas>

Historically, increases in global agricultural production have been achieved through the significant use of fossil fuels. Productivity increases have often been accompanied by negative effects on agriculture’s natural resource base. This situation is further compounded by the impact of climate change on the resilience of agricultural systems. Managing climate risk while simultaneously improving efficiency and productivity of agricultural systems is crucial to ensuring food and nutrition security. This is the main goal of climate-smart agriculture. The author of this paper explores the different options that allow for the joint production of food and energy in a “climate-smart” way and explain how integrated food-energy systems can contribute to improved food security and nutrition. They note that energy is a prerequisite for the provision of safe and nutritious food but that globally the high dependence on unsustainable woodfuel has large negative environmental effects, whilst also limiting the adaptive capacity of households. The authors therefore explore integrated food-energy systems at the field level through several case studies, where the production of biomass for energy can enhance food security and contribute to quality diets through the production of safe and nutritious food. For instance, small farmers can incorporate agricultural practices such as intercropping, organic agriculture, conservation agriculture, integrated crop-livestock management, and agroforestry. In many of these cases, excess agricultural/woody residues are available that can be used for energy.

**Sharma, N., Bohra, B., Pragya, N., Ciannella, R., Dobie, P., & Lehmann, S.** 2016. Bioenergy from agroforestry can lead to improved food security, climate change, soil quality, and rural development. *Food and Energy Security,* 5(3). [Cited 15 November 2021]. <https://doi.org/10.1002/fes3.87>

Like many of the other papers cited here, this paper explores the *positive* relationship between bioenergy and food security. The authors begin by acknowledging that the push for increased bioenergy has not always been successful, and has, in many cases, led to increased pressure on food systems, food prices, and destruction of biodiversity. In this paper, a strong case is made favouring the role of agroforestry systems and practices in sustainable bioenergy. The main objectives of this study are to evaluate the potential of bioenergy from agroforestry systems, specifically, to improve livelihoods and food security. Trees provide food for people including nuts, fruits, vegetables, and oils, which are important in maintaining nutrition security. Additionally, trees provide several ecosystem services such as improving soil quality and water management, both of which can improve the overall quality of crop yields. Agroforestry as a source of energy presents interesting opportunities for the sustainable development of bioenergy. Liquid biofuels have been gaining attention as a renewable energy source with the potential to improve energy security, mitigate climate change and revitalize agriculture economies. Demand for ethanol is expected to more than double in the coming years, placing pressure on the development of new feedstock and technologies. Trees provide sugar-rich sap or fruit pulps, which can be fermented and processed into ethanol.

**Kline, K.L., Msangi, S., Dale, V.H., Woods, J., Souza, G.M., Osseweijer, P., Clancy, J.S., Hilbert, J.A., Johnson, F.X., McDonnell, P.C., & Mugera, H.K.** 2017. Reconciling food security and bioenergy: Priorities for action. *Global Change Biology Bioenergy,* 9. [Cited 1 November 2021]. <https://doi.org/10.1111/gcbb.12366>

The authors of this paper took an approach to the relationship between biofuels and food security that differs from that of the other papers cited in this literature review. This paper aims to deconstruct the assumption that the relationship between biofuels and food security is negative (i.e., that the production of biofuels causes/further exacerbates food insecurity). While this paper does not explicitly dive into the links between bioenergy and nutrition security, specifically, it may present helpful information on how to develop bioenergy projects without compromising food security. The authors cite that bioenergy projects that improve resilience can reduce vulnerabilities that ultimately lead to food insecurity, which is defined by the authors as the “Absence of food security; condition exists when people suffer or are at risk of suffering from inadequate consumption to meet nutritional requirements; may be classified as chronic (long term), acute (transitory), cyclical, or critical (see famine); typically measured via multiple indicators of malnutrition”. One method the authors propose to accomplish this is to facilitate the transition of households from livelihoods that are subject to high levels of variability, such as subsistence farming dependent on a single crop towards more stable sources of revenue and income. However, the paper does not highlight any examples of how this solution can be achieved, without compromising existing livelihoods. Production and expansion of bioenergy can foster social development. Bioenergy provides energy security for transport, which can broaden access to food, expand selling markets, and create employment opportunities. Energy security can also improve food processing and drying and storing of excess product.

**Koszel, M. & Lorencowicz, E.** 2020. Agricultural use of biogas digestate as a replacement fertilizer. *Agriculture and Agricultural Science Procedia,* 15. [Cited 7 December 2021]. <https://doi.org/10.1016/j.aaspro.2015.12.004>

One of the predicted uses of the byproduct of bioenergy production is as a replacement for non-organic (or chemical) fertilizers. This paper explores how the use of agricultural biogas digestate can act as a replacement for non-organic fertilizers typically used in agricultural production. Digestate is typically defined as liquid from anaerobic decomposition of animal and plant waste. It contains considerable amounts of mineral elements such as nitrogen, potassium, and phosphorus. When digestate is used as a fertilizer, it improves soil quality, plant quality, and plant immunity to biotic and abiotic agents. In this study, the authors focused on the use of biogas digestate on alfalfa cultivation. For comparison, alfalfa was also cultivated on a separate field that used mineral fertilizer. The study found that the content of phosphorus, magnesium, and potassium rose in the soil that was treated with digestate. The increase in potassium content specifically, is an important result, as potassium is a macroelement that has fundamental significance for plant nutrition. It plays a key role in plant water balance, activates enzymes, takes part in the process of photosynthesis and transportation of assimilates, and activates sensitivity of water stress associated with drought. This is an important consideration for the use of bioenergy and its byproducts to improve the nutrient quality of food crops.

**Muscat, A., de Olde, E.M., de Boer, L.J.M., & Ripoll-Bosch, R.** 2020. The battle for biomass: A systematic review of food-feed-fuel competition. *Global Food Security*, 25. [Cited 30 October 2021]. <https://doi.org/10.1016/j.gfs.2019.100330>

Can bioenergy and food security exist together? Is competition for space and other biophysical resources inevitable? These are the fundamental questions Muscat *et al.* (2020) addresses in this article. The authors identified several factors for the effective use of resources to meet the demands of food, feed, and fuel. Humanity faces the challenge of feeding a growing population and supplying its energy needs within biophysical boundaries. Additionally, there are concerns regarding whether enough biomass can be produced for animal feed in the context of growing demand for animal source food and environmental impact. Food, feed and fuel production are continuously competing for economic and natural resources. Increasing demand for bioenergy results in increased land use, higher land rents, loss of forests and pastures as they are converted to arable land, and increased food prices and/or agricultural commodity prices. Muscat *et al.* 2020 identifies producer-side, governance, consumption-side, and loss and waste-based solutions to creating more of a balance between food, feed and fuel, without compromising the nutritional value of food. Producer-side solutions are focused primarily on minimizing competition between bioenergy and food production, such as planting bioenergy crops on land not suitable for food production, or “marginal lands.” Governance solutions focus on addressing the competition for bioenergy from a policy perspective, such as placing larger emphasis on increasing the efficiency of global food supply chains. Consumption-side solutions focus primarily on creating greater balance in the human diet.

**Ayaz, M., Feizienè, D., Tilvikienè, V., Akhtar, K., Stulpinaitè, U., & Iqbal, R.** 2021. Biochar role in the sustainability of agriculture and environment. *MDPI Sustainability,* 13(1330). [Cited 8 November 2021]. <https://doi.org/10.3390/su13031330>

The authors of this paper sought to explore the potential role of biochar in the perpetuation of sustainable agriculture. Like other papers explored in this literature review, the authors first began by emphasizing the conflict between the growing pressure on agricultural systems to provide food for an increasing population and the role of these agricultural systems on global climate change. Chemical fertilizers, the use of which have increased exponentially in recent years, may increase crop yield, but they also risk the sustainability of the environment by provoking key ecological disparities, such as biodiversity loss, global warming and inclusion of heavy metals in living organisms. Thus, it is essential to adopt a more natural way of farming, which will reduce the reliance on non-organic fertilizers and sustain agricultural production and productivity. Biochar may provide this opportunity[[2]](#footnote-2).

The authors explore the ways in which biochar can be used to improve modern agricultural systems, including strengthening soil fertility, improvement in soil microbial activity, and improvement of nutrient availability such as nitrogen and phosphorus. The additions of biochar with organic matter are increasingly gaining attention regarding their influence on soil fertility and crop yield. In addition to increasing crop yield through improving efficiency of water use and improvement of soil pH and quality, evidence suggests that use of biochar may be beneficial for carbon sequestration to reduce CO2 emissions. While the impact of biochar on reducing CO2 emissions along the agricultural value chain may not directly impact nutrition, it may be a significant contributor to advancing climate-smart agriculture. Biochar application is an effective practice for restoration of the functionality of degraded soils, and the maintenance of long-term soil fertility and functions. The addition of biochar improves the degraded and low-quality soils, to improve overall crop production.

**Blair, M.J., Gagnon, B., Klain, A., & Kulišic, B.** 2021. Contribution of biomass supply chains for bioenergy to Sustainable Development Goals. *MDPI Land,* 10(2). [Cited 1 December 2021]. <https://doi.org/10.3390/land10020181>

The authors of this paper sought to explore the role of bioenergy in the achievement of the Sustainable Development Goals (SDGs). Making progress towards the SDGs will require a holistic approach that recognizes a multitude of objectives and stakeholders. The expansion of bioenergy is perhaps the best example of this approach, as the sustainable production of bioenergy relies on biomass, which can have significant environmental, socioeconomic, and health impacts for people and communities. Currently, about half of the global bioenergy supply comes from traditional applications, such as wood burning fires and cookstoves. Traditional bioenergy is expected to decline as modern equipment and systems, which are designed to increase energy efficiency and reduce pollution, are deployed to developing nations. The authors examined the impact of the use of bioenergy on SDG 2, 7, 8, 9, 12, 13, and 15. The authors include the positive and negative impacts of the use of bioenergy in their analysis. While all SDGs are important in the achievement of food security and nutrition, SDG 2 (zero hunger) is perhaps the most relevant to this literature review. The supply of agricultural biomass is intrinsically linked to SDG 2, as supply chains are typically integrated within food production systems. Careful integration is required to ensure that biomass supply does not negatively impact soil quality, productivity, or compete with food crops for land and that farmers will be able to benefit from crop diversification, improved productivity, and sustainable land management. Indirectly, the expansion of bioenergy to achieve food security can contribute to achieving SDG 3 (good health and well-being). Energy crops can remove pollutants from the air, water, and soil, improving the overall quality of crops. Planting energy crops for bioenergy production could also help lower the overall level of CO2 in the atmosphere by acting as carbon sinks (when planted on degraded land) while in turn, producing lower carbon fuels. Another indirect mechanism by which bioenergy use can aid in achieving nutrition security is using digestate. Digestate from anaerobic digestion can be applied to crops as fertilizer, reducing the need for synthetic fertilizers.

Bioenergy differs from other renewable energy sources such as wind, solar, and geothermal, because bioenergy requires the procurement of varying amounts of sustainably sourced biomass to generate energy. While this may have many positive impacts on households and communities, without proper oversight and implementation, expansion of bioenergy may adversely impact ecosystems.

**Trigo, E., Chavarria, H., Pray, C., Smyth, S.J., Torroba, A., Wesseler, J., Zilberman, D., & Martinez, J.F.** 2021. *The Bioeconomy and Food Systems Transformation.* United Nations Food Systems Summit 2021. Also available at <https://sc-fss2021.org/wp-content/uploads/2021/03/FSS_Brief_Bioeconomy_and_Food_Systems_Transformation.pdf>

This brief, which was prepared for the United Nations Food Systems Summit in 2021, is aimed at identifying the ways in which the bioeconomy contributes to the transformation of food systems. Transforming the global food system requires several integrated actions to ensure the availability of safe and nutritious food for everyone. This requires increasing crop and livestock yields through sustainable intensification activities in multifunctional landscapes, the diversification of production, and good soil management practices, all of which can be achieved through the integrated use of bioenergy. Additionally, ensuring resilience of vulnerable communities is an important component of transforming the global food system. Resilience can be strengthened through the bioeconomy by aiding to diversify agricultural commodity production, increasing the use of bio-based inputs in agriculture, and the diversification of rural incomes into rural production of bioenergy.

**Part II: Case Studies**

*Questions to Address:*

* *How do these links function in practice?*
* *What are the examples of good practice?*

**Summary of Part II Findings**

* Land availability for energy crop production varies greatly from country to country
* Climate-smart agriculture and marginal land are not universally defined; will have varying impacts from country to country, depending on the definitions used
* Many differences between regions/countries; collection of more case studies is needed. An exploration of *grey* literature might be needed to identify potential case studies that are relevant for food security and nutrition.

**Simon, S., & Wiegmann, K.** 2009. Modelling sustainable bioenergy potentials from agriculture for Germany and Eastern European countries. *Biomass and Bioenergy,* 33. [Cited 22 November 2021]. <https://doi.org/10.1016/j.biombioe.2008.10.001>

The authors of this paper assess the potential of agricultural biomass for sustainable energy production for Germany, and compares it to results from Poland, the Czech Republic, and Hungary. To complete these analyses and comparisons, the authors looked to the HEKTOR model, which was developed in Germany and then transferred to other regions. The model assumes that all agricultural area not in use for food production is available for biomass production. The authors present two scenarios for the future of bioenergy potential from agriculture: the reference scenario assumes business as usual, while the sustainability scenario indicates a consistent implementation of sustainability goals. One of the variables the authors looked at was available land use. In their analysis, they found that in the sustainability scenario, available land use for biomass production was limited due to the expansion of organic and extensive farming. Additionally, the preservation of land for nature conservation also limited available land under the sustainability scenario. The findings of the paper highlight that there can be a conflict between enhancing sustainability goals and increasing biofuel and biomass production, which is important to note.

**Gorsens, J., Lu, Y., He, G., Bluemling, B., & Beckers, T.A.M.** 2013. Sustainability effects of household-scale biogas in rural China. *Energy Policy,* 52. [Cited 9 December 2021]. <https://doi.org/10.1016/j.enpol.2012.11.032>

Similar to the Koszel & Lorencowicz (2015) paper in Part I, the authors of this paper identified the ability of biogas to replace traditional energy and chemical fertilizer as an important consideration to expand biogas. Rural populations in developing nations largely rely on fuels such as fuel wood, coal, and crop residues for heating and cooking. The use of these fuels is determinantal to indoor air quality and have had negative impacts on human health. In addition, these fuel types have substantial environmental impacts; their carbon emissions contribute to the acceleration of climate change and forest fuels contribute to deforestation. The replacement of chemical fertilizer use with the biogas slurry (also called digestate) may, in turn, improve water quality as the digestion process improves the bioavailability of nutrients in the manure and kills pathogens. The authors of this paper sought to explore the promotion of household biogas as a solution for sustainable energy use in rural areas, specifically in rural China. The primary focus of this study was to examine how household-scale biogas effectively contributes to sustainability.

**Tanumihardjo, S.A., McCulley, L., Roh, R., Lopez-Ridaura, S., Palacios-Rojas, N., & Gunaratna, N.S.** 2020. Maize agro-food systems to ensure food and nutrition security in reference to the Sustainable Development Goals. *Global Food Security,* 25. [Cited 2 November 2021]. <https://doi.org/10.1016/j.gfs.2019.100327>

This paper expands upon examples of the food-fuel competition described by Muscat *et al.* 2020. Maize is among the three most important crops in the world, providing almost half of daily energy to Africa and the Americas. Demand for maize, as population growth continues, will require dramatic increases in production. In addition to population growth, demand for maize has increased due to its utilization as a bioenergy crop. Increased demand, coupled with climatic changes are putting pressure on the availability of this crop around the world. The nutritional aspects of maize have been well studied and analyzed. Sustainable development in Africa and much of Latin America continue to rely on maize as a primary source of energy and nutrition. The use of maize as a source of biofuel is a cleaner energy source than energy generated from fossil fuels. Studies conducted by the United States Division of Agriculture (USDA) have concluded that if current trends in biofuel production continue, through 2022, that corn ethanol production will result in an estimated 44% reduction in greenhouse gas life cycle, compared to gasoline. In many places around the world, including regions in Africa, reliable access to electricity is limited. This, in addition to the growing instability of oil prices, presents an opportunity for the expansion of biofuels, creating more pressure on the demand for maize.

**Beattie, S. & Sallu, S.M.** 2021. How does nutrition feature in climate-smart agricultural policy in Southern Africa? A systemic policy review. *MDPI Sustainability,* 13. [Cited 11 November 2021]. <https://doi.org/10.3390/su13052785>

The impacts of growing pressure on global food systems will disproportionately impact the global south. This paper specifically looks at the challenge of producing and supplying food that is both nutritious and environmentally sustainable in southern Africa. In the coming years, African nations will need to improve the nutritional status of 256 million people currently considered undernourished while simultaneously increasing demands for agricultural production. The authors of this paper identified that there is a knowledge gap, on the relationship between CSA and nutrition, especially within CSA policy implementation. Therefore, the authors were interested in understanding what constitutes an enabling policy environment for the incorporation of nutrition into CSA related policy. The authors identified approximately 112 CSA policy publications from Malawi, Tanzania, and Zambia, and sought to understand to what extent nutrition is included in these policies. All these policies incorporated at least one CSA related practice into their objectives. The most common practices mentioned in these policies are sustainable soil and water management practices, with improved irrigation and water management systems subsequently deemed a priority. Actions to address nutrition security are mentioned in approximately 59% of the documents, with the most common method of improving nutrition security being the diversification of crop production. It is expected that by diversifying the crop production, a more diverse and nutritious range of produce can be obtained at the rural household level. While there is currently no universally agreed upon definition of CSA, Beattie and Sallu define it as “an approach considered capable of transforming and realigning agricultural systems to support food and nutritional security, and development under a changing climate” (1). For sustainable food and nutrition security to be achieved, effective policy environments that supports the widespread adoption of CSA application are required. Scaling up the use of bioenergy can improve access to modern energy for agricultural production, which can increase agricultural productivity.

**Part III: Potential Policy Implications**

*Questions to Address:*

* *How can these findings be used to support policy making?*
* *How can these findings encourage cross-sectoral partnerships and influence funding of projects and designs?*

**Summary of Part III Findings**

* Policies that enhance synergies and mitigate trade-offs between bioenergy production and nutrition will vary greatly from region to region
* Globally used/determined definition of climate-smart agriculture will make CSA targets easier to monitor and analyze progress
* Use of marginal land or degraded land for energy crop production may address a primary component of the food versus fuel debate
* More discussion of nutrition and bioenergy in policy spaces can encourage greater stakeholder participation
* Improving definitions of different land types on a national level is needed
* Improved governance of land use and land use change on a national level is needed
* International implications include greater discussion and improvement of linkages between SDG 2 and SDG 7

**Campbell, J.E., Lobell, D.B., Genova, R.C., & Field, C.B.** 2008. The global potential of bioenergy on abandoned agriculture lands. *Environmental Science and Technology,* 42(15). [Cited 1 December 2021]. <https://doi.org/10.1021/es800052w>

A common criticism of bioenergy is that it competes for limited land space with agriculture and exacerbates CO2 emissions. Converting forest lands into dedicated energy crops could accelerate climate change by removing natural carbon sinks and emitting carbon stored in forests. In contrast, converting agricultural lands into agriculture for bioenergy could threaten food security and increase the cost of foods that are critical for nutrition security. Both problems can potentially be avoided by establishing bioenergy agriculture on abandoned agriculture lands. Assessing the global potential of bioenergy production from agriculturally degraded or abandoned land is challenging because of the uncertainty associated with the spatial extent of these lands and the potential plant production on these lands. The authors of this paper sought to understand approximately *how much* land is available for bioenergy production but do not delve into the agricultural and/or energy implications of this choice.

**Shortall, O.K.** 2013. “Marginal land” for energy crops: Exploring definitions and embedded assumptions. *Energy Policy,* 62. [Cited 2 December 2021]. <https://doi.org/10.1016/j.enpol.2013.07.048>

One of the most controversial aspects of bioenergy expansion is that of the implications of land-use change. Production of biomass on agricultural land has raised several controversies: many believe competition for land use between food crops and fuel crops leads to higher food prices, spurring the infamous food versus fuel debate. There is also the issue of the direct and indirect impacts of the destruction of natural land, including the destruction of natural carbon sinks and the release of stored CO2. The authors of this paper explore those controversies with the aim to better understand the potential use of marginal land for bioenergy production. The production of bioenergy from wastes or residues is another mechanism proposed to address these controversies. The two main controversies the authors explore in their study are as follows: 1) how is “marginal land” defined? and 2) how would claims of marginal land be put into practice?

The first definition the authors addressed in their analysis classified marginal land as land where food production cannot take place because the land is not productive enough. This includes land where soil quality is poor, harsh weather conditions exist, or that has been degraded through processes such as deforestation. Using this definition, the assumption is made that enough of this land exists to produce a substantial amount of biomass. This assumption has been criticized by NGOs, scientists, and academics in particular context to the global South. This definition also assumes that structures exist to ensure that marginal land will be used to produce energy crops. Globally, marginal land, if available, can be used for purposes other than energy crop production. This definition assumes that countries have political and economic structures in place to allocate these lands for specific purposes. The second definition identified is oriented toward the quality of agricultural land; the land is not necessarily unsuitable for food production, but food production is less productive. The third and final definition seeks to circumvent some of the criticisms brought upon by the first two definitions. The third definition asserts that marginal land is land where cost effective agricultural production is not possible under a given set of conditions. Under this definition, the “marginality” of land can only be determined in reference to the economic opportunities offered by the array of land use choices available locally at the moment. The differentiations between the three definitions may help to inform the development of biomass policy frameworks with important implications for food security and nutrition.

**Part IV: Use of preliminary findings**

*Questions to Address:*

* *What are the most effective ways in which to enrich these preliminary findings?*
* *How can this literature review encourage future discussion on this topic?*

1. **Discussion-based Forum provide by GBEP.** Hosting a forum in which members can discuss their own findings on the relationship between bioenergy, food security and nutrition, as well as discuss good practice examples of this from their own country, would allow for a wider perspective on this topic that cannot be found through peer-reviewed literature. This type of forum would have a free-flowing nature. Beforehand, GBEP members would receive a “template” containing the main questions and topics to be discussed at the forum. Key sustainability indicators identified by GBEP might be helpful to identify potential impacts that could be relevant for nutrition such as: land use change, including indirect effects on food security and food prices; soil quality; water quality; use of modern bioenergy stoves, including effects on indoor smoke and time spent by women and children in collecting biomass and; energy diversity and security to improve efficiency of agri-food systems. Participants should come prepared to discuss the topics listed.
2. **Infographics** that showcase where nutrition security and bioenergy are linked along with the food systems and specific value chain.

1. Tirado et al. use FAO’s definition for the Food Insecurity and Vulnerability Information and Mapping Systems (FIVIMS) for food insecurity and malnutrition. Malnutrition is defined as “an abnormal physiological condition caused by deficiencies, excesses or imbalances in energy, protein and/or other nutrients”. [↑](#footnote-ref-1)
2. This is further corroborated by other studies focusing on the substitution of chemical fertilizer. For examples, please see:

   **Fang, P., Abler, D., Lin, G., Sher, A., & Quan, Q.** 2021. Substituting organic fertilizer for chemical fertilizer: Evidence from apple growers in China. *MDPI Land,* 10. [Cited 17 February 2022]. <https://doi.org/10.3390/land10080858>

   **Kizito, S., Luo, H., Lu, J., Bah, H., Dong, R., & Wu, S**. 2019. Role of nutrient-enriched biochar as a soil amendment during maize growth: Exploring practical alternatives to recycle agricultural residuals and to reduce chemical fertilizer demand. *MDPI Sustainability,* 11. [Cited 17 February 2022]. <http://dx.doi.org/10.3390/su11113211> [↑](#footnote-ref-2)