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ASSESSMENT OF TRADE-OFF DECISIONS FOR SUSTAINABLE BIOENERGY DEVELOPMENT IN THE PHILIPPINES: AN APPLICATION OF CONJOINT ANALYSIS

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Abstract:

Sustainability assessments of bioenergy production are essential because it can have both positive and negative impacts on society. Human preferences that influence trade-off decisions on the relevant determinants and indicators of sustainability should be taken into account in these assessments. In this paper, we conducted a survey with five groups of respondents including (1) government officials and employees, (2) academic and research professionals, (3) private company managers and workers, (4) farm owners and workers, and (5) "others" (e.g. students, residents, etc.) to assess their trade-off decisions on bioenergy development in the Philippines. The analysis of the survey results reveal that sustainability of bioenergy production will depend on the choice of biomass feedstock and these choices depend on people's perceptions. Heterogeneous perceptions among the different groups of respondents on the appropriate bioenergy feedstock to achieve economic, social and ecological sustainability suggest that sustainability of bioenergy is not a generic concept. The use of aggregate indices for sustainability assessments that ignore these perceptions on bioenergy production can thus be very misleading. The preference weights from conjoint analysis, which measure human preferences on different determinants and indicators of economic, social and ecological sustainability, can help improve sustainability assessments.

1 Introduction

Bioenergy production can have both positive and negative impacts on society. On the one hand, reduction in green house gases (GHG) emissions, increase in energy security, promotion of rural development, and increase in export revenues are the most cited arguments for bioenergy production (e.g. Bento 2008, Ravindranath et al. 2008, Demirbas and Demirbas 2007, Chum et al. 2011). On the other hand, the recent undesirable experiences concerning, among others, regional food availability and accessibility (e.g. Naylor et al. 2007, Braun 2007, Lustig 2008), forest degradation (e.g. Brühl and Eltz 2010, Ceccon and Miramontes 2008, Sasaki et al. 2009), and social conflicts (e.g. Cotula, Dyer, and Vermeulen 2008, Hall et al. 2009, Ariza-montobbio and Lele 2010) are key contemporary controversies confronting the bioenergy sector. Opinions are at odds because the institutional structure of bioenergy is complex. Bioenergy production involves different products, different sectors and a range of actors interacting at and across different levels (Clancy 2008). Thus it not only provides opportunities to generate multiple benefits apart from energy generation, but also causes conflict with many interests due to these inter-linkages (Faaij 2006). Developing a bioenergy sector that is sustainable is thus an immense challenge because the long-term maintenance of economic, social and ecological well-being is not that straightforward. The sustainability of bioenergy is broadly gauged on its economic, social and ecological impacts. Understanding the scope and magnitude of these impacts depends largely on how we frame the interconnections and interdependencies between the economic, social and ecological determinants of sustainability. In this paper, we build on a framework for assessing the sustainability of bioenergy production that we have previously proposed, called STRAP (sustainability trade-offs and pathways) approach (Acosta-Michlik et al. 2011). In this approach bioenergy sustainability is defined based on a region's capacity to achieve a balance between economic stability, social equity and resource productivity. For each sustainability dimension, we have identified the most relevant sustainability determinants based on available relevant theories and evidences from case studies. Energy security, technology diffusion and market organisation are the determinants for economic stability; food security, welfare contribution and social exclusion for social equity; and feedstock options, resource capacity and land management for resource productivity. These determinants not only represent the complementary and/or competitive views on the use of first and second generation bioenergy crops for food and fuel production, but also capture the inherent potential contradictions and controversies in achieving a balance between the three sustainability dimensions.

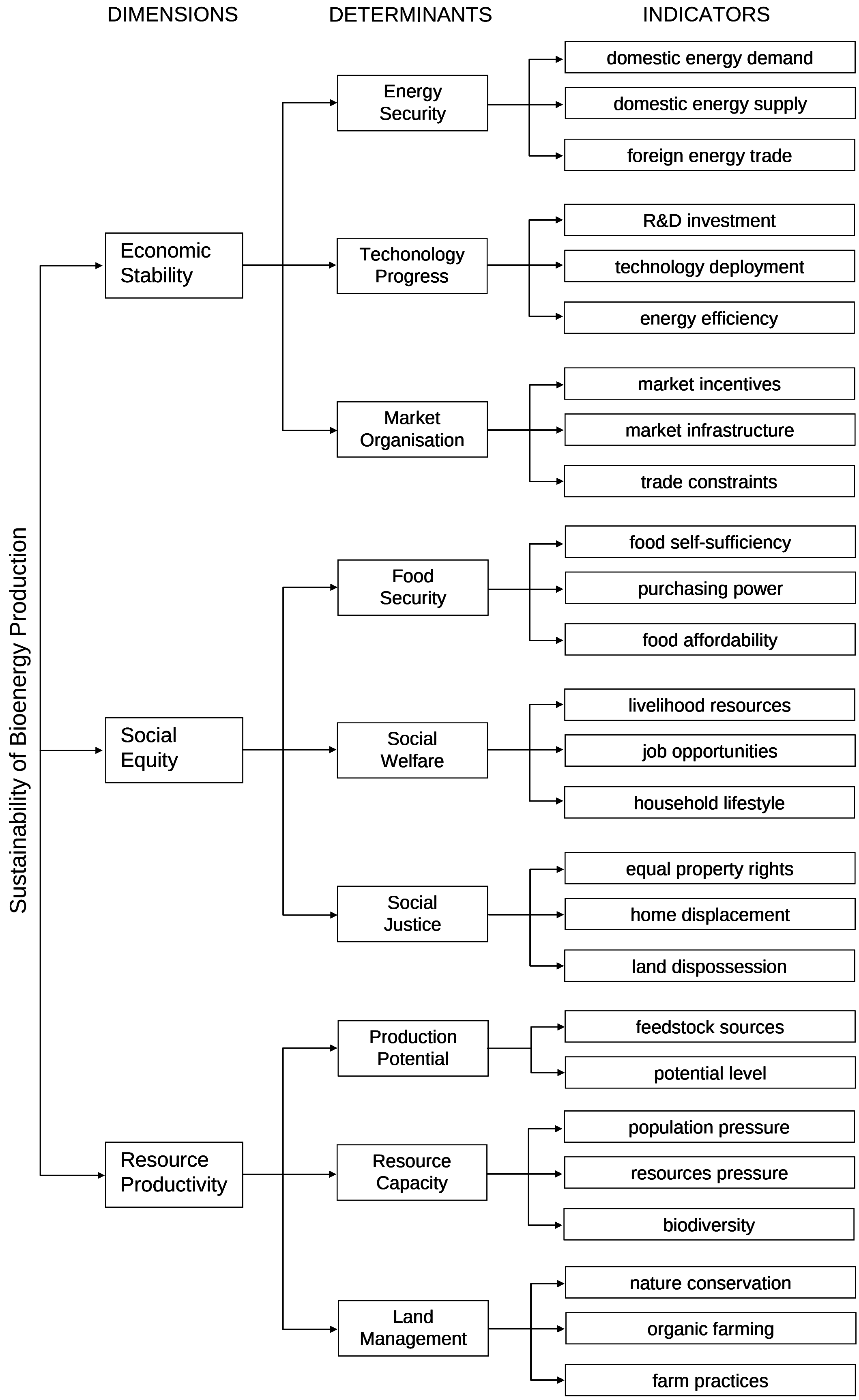
Although the determinants of sustainability are valued differently in different regions or societies, in practice, they are at present combined somewhat arbitrarily into aggregated indices. Individual judgements and decisions that are critical to achieving the right balance between economic, social and ecological determinants are thus often neglected in sustainability assessments, decreasing the likelihood of broad acceptance of a balanced strategy by key actors and participants. Keeping a balance does not necessarily mean equal allocation but logical distribution of weights according to human needs and preferences. Sustainability assessment should thus set off from understanding how and why a society trades off one objective for the other to achieve its goals. In this paper, we aim to contribute to an understanding of trade-off decisions by a society through developing an empirical application to the STRAP framework. To do this, we followed the method of Sydorovych & Wossink (2008), who were first to apply conjoint analysis to elicit preferences on agricultural sustainability. However, this paper improves the application of conjoint analysis for sustainability assessment in two aspects. First, whilst Sydorovych and Wossink took a very broad approach in assessing agricultural sustainability, we are more explicit in defining the context of the assessment. We explicitly link the determinants of sustainability to particular types of agricultural crops. This is important because sustainable development depends on the resource requirement, production structure, market infrastructure, welfare contribution, etc. of a specific agricultural system. Second, whilst their work only serves a pedagogical purpose thus justifying the use of a non-representative sample, here we applied the method to estimate utilities and preference weights that can be further used for assessing sustainability trade-offs and creating more sensible aggregate sustainability measures for bioenergy crops. Through a survey we elicited preferences of people who are working in the government, academe/research, private companies, on farm and others regarding their perception of different economic, social and ecological determinants of sustainability in the Philippines. The paper is organized as follows: The concept that frames our understanding of the sustainability of bioenergy development is presented in section 2. Section 3 presents the methods for the conjoint analysis and describes the survey design as well as the case study area. We discuss our results in section 4 and present our conclusions in section 5.

2 Conceptual framework

An appropriate framework, which guides the selection of determinants and indicators, is indispensable for the assessment of sustainability trade-offs using conjoint analysis (see section 3.1). We describe sustainability using three dimensions – economic stability, social equity, and resource productivity (Figure 1). These dimensions are represented by determinants, which are issues or phenomena that significantly influence the nature of sustainability. For determinants with abstract meanings, indicators provide a benchmark to quantify and simplify the concept or idea they represent. Below is a summary of the interconnections and interdependencies between the different determinants and indicators of social, economic and ecological dimensions of sustainability to illustrate the complex structure of bioenergy development. A more detailed discussion is available in Acosta-Michlik et al. (2011).

Energy security is an important public concern because energy is central to attaining stable economic growth. The most important indicators of energy security include energy demand, supply and trade (Figure 1). The idea of reducing dependence on foreign sources of energy through local bioenergy production has increased the political popularity of biofuels (Doornbosch and Steenblik 2007, Eickhout et al. 2008, Jumbe, Msiska, and Madjera 2009), resulting in generous government targets for substituting biofuels for fossil fuels in the transport sector. The ability to substitute imported fossil fuel with domestic biofuel depends not only on the available land but also on the available conversion technologies. The diffusion of technologies is thus an important determinant of bioenergy development, with R&D investment and deployment as well as energy efficiency of these technologies as the most relevant indicators. The technical and cost (or techno-economic) efficiencies of bioenergy technologies ultimately influence the diffusion of bioenergy in the market (Ravindranath and Balachandra 2009). Mayfield et al. (2007) argue, however, that significant gains in the areas of research, development and education alone will not guarantee success in the biomass industry. The sector needs a well-organised market to utilize the product. Thus, the market for bioenergy needs to be organised to achieve its potentials. The most important indicators of market organisation include the development of market infrastructure, provision of market incentives, and elimination of trade constraints. Unlike other technologies where necessary infrastructure is established only after achieving a certain critical dissemination in the market, new bioenergy technologies cannot reach this required minimum diffusion without necessary infrastructure in place (Rösch and Kaltschmitt 1999). Policy incentives not only to promote technologies but also to develop market are thus necessary to make the biomass a competitive source of energy and support the growth of bioenergy sector (McCormick and Kaberger 2007, Hughes 2000, Junfeng and Runqing 2003, Thornley and Cooper 2008). National policies should support both domestic market and foreign trade for bioenergy to develop a sector that is capable of contributing to social and ecological sustainability.

Figure 1 Sustainability framework for trade-off analysis



The trade prospects created through bioenergy policies in developed countries have made bioenergy an appealing avenue for increasing foreign exchange revenues in developing countries. However, bioenergy trade in recent years had undesirable impacts on food security. The recent controversies on the impacts of bioenergy production on food availability and affordability made food security one of the most urgent contemporary public issues regarding the sustainability of bioenergy production. The levels of food self-sufficiency and affordability as well as purchasing power are some of the useful indicators of food security (Figure 1). The drastic increase in prices of major food commodities in 2007 and 2008 caused a food crisis that resulted in protests and riots in many developing countries (Rosegrant 2008, Lustig 2008). Rapid price increases in food commodities have considerable impacts on poverty, which can undermine rural development. The contributions of the bioenergy sector to welfare through livelihood and employment generation are the most important indicators related to rural development. Bioenergy production is claimed to generate rural livelihood by increasing agricultural demand, rural employment and agricultural land base (i.e. through the use of marginal and idle lands) (Clancy 2008, Ewing and Msangi 2009, Hazell and Pachauri 2006). Although there are few cases of success on livelihood generation (e.g. Rist, Feintrenie, and Levang 2010, Larson and Kartha 2000), many remain sceptical of the role of bioenergy in welfare development due to many infrastructural (Godfray et al. 2010), technological (Ewing and Msangi 2009) and organizational (Garcez and Vianna 2009) barriers. Agglomeration and investment of capital have the potential to increase the efficiency of production and produce employment in the rural sector. However, if left unregulated, they could push rural dwellers and small farmholders off their land to pave the way for commercial exploitation of biofuels (Cotula, Dyer, and Vermeulen 2008, Jumbe, Msiska, and Madjera 2009, Van Wey 2009), particularly in developing countries with insecure land tenure or without clear property rights (Rist, Feintrenie, and Levang 2010, Karekezi and Kithyoma 2006). Policies should thus ensure social equity not only through generation of livelihood and employment but also through protection of social justice so that rural populations could benefit from technological innovation in the bioenergy sector. Improvement in lifestyle is another useful welfare contribution of modern bioenergy technologies because energy consumption is among others essential to the provision of basic needs (e.g. food, clean water, health, shelter, etc.).

The sources of biomass feedstock, which can be categorised as first generation and second generation crops, are an important determinant of ecological sustainability of bieonergy production. Bioenergy policies since the 1980s have promoted technologies to convert biomass from first generation crops; i.e., from sugar- and starch-rich crops into ethanol and to convert vegetable oil (e.g. rapeseed, soybean) and palm oil (e.g. palm, coconut) into biodiesel. The biomass feedstock for these biofuels and the associated conversion technologies are not sustainable, however, because mostly they have negligible effect on GHG mitigation, reduce biodiversity, compete with land use for food production, and have high costs of production (e.g. Hamelinck and Faaij 2006, Girard and Fallot 2006, Yan and Lin 2009). The use of food crops for bioenergy production will further strain both land and water resources, which are already under pressure from food, habitat and commercial needs of the rapidly growing population. Thus, it is important to determine the relationships of the feedstock options to the resource capacity, which most relevant indicators can be described in terms of resource availability (i.e. land, water), ecological sensitivity (i.e. soil quality, biodiversity and climate mitigation) and population pressure (i.e. density and growth) (Figure 1). More recently, attention is given to alternative sources of biomass feedstock not only to produce energy- and cost-efficient bioenergy, but also to contribute to popular social concerns like rural development, food security and environmental protection. Second generation bioenergy using feedstock from agriculture or forest residues, fast-growing trees, perennial grasses, and algae offers a promising techno-economic solution because of larger energy yields per hectare due to broadness of the feedstock base and lower production costs per hectare due to the use of marginal lands and less management (e.g. Hamelinck and Faaij 2006, Londo et al. 2010, Gomiero, Paoletti, and Pimentel 2010). Although there are potentials to develop the technologies required to process second generation bioenergy feedstock, environmental concerns remain that require attention. These include increased soil erosion due to the use of marginal lands for wood production and decreased soil fertility due to the removal of agricultural residues in the agro-system. Some authors suggest however that many of the bioenergy production dilemmas could be solved through appropriate land use management. Perennial bioenergy crops should be considered a component of conservation farming systems to improve soil quality and reduce erosion (Dale et al. 2010).

3 Methods

This section explains the methods that we used to apply the sustainability framework described above in the assessment of trade-off decisions on bioenergy in the case study area. Conjoint analysis is the method used for generating the trade-off estimates and survey is the method used for collecting the data for the analysis.

3.1 Conjoint analysis

Conjoint analysis (also known as choice models or experiments) is a practical technique for measuring preferences and assessing trade-off decisions. This is a technique widely used in different scientific fields including psychology, transport, economics, and environment to transform subjective choice responses into estimated parameters. Farber & Griner (Farber and Griner 2000) provide a summary of the application of conjoint analysis for environmental valuation. In conjoint analysis the attributes of an environmental good are used to understand the general trade-offs which an individual is willing to make (Hanley, Wright, and Adamowicz 1998). Considerable attention has been given to this technique both in academe and industry to measure preferences through utility trade-offs among products and services (Lee et al. 2006, Green and Srinivasan 1990), particularly in agro-environments (e.g. Tano et al. 2003, Stevens et al. 2002, Moran et al. 2007, Blamey et al. 2000). Conjoint technique is suitable for analysing human decisions, particularly for understanding the process by which individuals develop their preferences for products or services (Sayadi, Roa, and Requena 2005). The preferences are assumed to be influenced by the individual's subjective perceptions on the presented choices. Thus, the preference structure is a function of the individual's economic, social and cultural conditions, which affect his or her decision. Public preferences have an important role in decision-making because they may in fact highlight stark policy trade-offs (Hall et al. 2004). Moreover, conjoint measurement assumes that a product can be described according to the levels of a set of attributes, and the consumer's overall judgement with respect to that product is based on these attribute levels (Sayadi, Gonzalez-Roa, and Calatrava-requena 2009). In choice-based conjoint analysis, a set of attributes and their respective levels define the respondents' choices. Specifically, the combinations of attribute levels define the choice tasks in conjoint surveys (see section 3.2). A conjoint study leads to a set of part-worths or utilities that quantify respondents' preferences for each level of each attribute (Orme 2010). It is a measure of relative desirability or worth so that the higher the utility, the more desirable is the attribute level (Orme 2006).

In a conjoint survey, the respondents are presented several choice tasks and they choose one option in each task. In this paper, the responses from the survey were analysed using a Hierarchical Bayes Choice-based Conjoint (HCBC) model that is able to capture preferences of individuals (i.e. respondent level) and groups of individuals (i.e. segment level) (Orme 2009):

(1) $Y_i = X_i \beta_i + \varepsilon_i$

(2) $\beta_i = \Theta z_i + \delta_i$

Where in the first equation $\boldsymbol{Y_i}$ is a vector of the responses from the choice tasks, $\boldsymbol{X_i}$ is a matrix of the attribute levels, $\boldsymbol{\beta_i}$ is the $\boldsymbol{p}$-dimensional vector of regression coefficients representing the utilities, and ε_i is a $\boldsymbol{p}$-dimensional vector of random error terms. In the second equation, Θ is a $\boldsymbol{p}$ by $\boldsymbol{q}$ matrix of regression coefficients (i.e. utilities), $\boldsymbol{z_i}$ is a $\boldsymbol{q}$-dimensional vector of covariates and δ_i is a $\boldsymbol{p}$-dimensional vector of random error terms. The HCBC model is called hierarchical because it models respondents' preferences as a function of a lower- or individual-level (within-respondents) model and an upper-level (pooled across respondents) model (Orme and Howell 2009). According to Lenk et al. (1996), hierarchical Bayes analysis creates the opportunity to recover both the individual-level part-worths and heterogeneity in part-worths, even when the number of responses per respondent is less than the number of parameters per respondent. This makes the model in equations (1) and (2) very useful in cases of small respondent population**,** where $\boldsymbol{i}$ = 1 ….n number of respondents. Equation (1) reflects the individual-level model and assumes that the respondent chooses options according to the sum of utilities as specified in logit models. Equation (2) is an upper-level model that describes the heterogeneity in the individual utilities across the population of respondents. The heterogeneity is captured in covariates describing the respondent attributes. These attributes can be demographic variables such as age, gender, etc. According to Orme and Howell (Orme and Howell 2009), however, the most useful covariates bring exogenous information (outside the information already available in the choice tasks) to the model to improve the utility estimates. In this paper, we introduce a-priori segmentation where the segments, which define similarities in preference/part-worth structures of homogenous respondents, are used as covariates in the model. Equations (1) and (2) were estimated using the multinomial logit solutions of the SSIWeb Sawtooth software (Orme 2010). When computing utilities using logit, every attribute level is assigned a utility or part worth (Orme 2006).

From the segmented conjoint utilities $\boldsymbol{\Theta}$ generated from equation (2), we computed the preference weights ($\boldsymbol{\omega}$) of the various attributes ($\boldsymbol{R}$) as follows:

(3) $\omega_{ij} = \left(R_{ij} / \sum_{i=1}^{n} R_j \right) * 100$

(4) $R_{ij} = \Theta_{ij}^{\max} - \Theta_{ij}^{\min}$

where $\boldsymbol{i}$ refers to attribute levels and $\boldsymbol{j}$ refers to the segments. The weights measure the relative importance of the different attributes to each other.

3.2 Survey design and administration

Based on the foregoing discussion, the attributes and the attribute levels are core to conjoint analysis. Table 1 presents the attributes and the attribute levels for the survey based on the sustainability framework in Figure 1. The determinants of economic stability, social equity and resource productivity represent the attributes and the indicators for these sustainability determinants represent the attribute levels in the survey design. In the discussion of the results, we will also refer to the sustainability determinants as attributes and sustainability indicators as attribute levels to conform to the terminologies used in conjoint analysis. Each attribute level is further defined according to its desirability for the society, which aims to make the respondents decide on trading-off between more and less desirable levels of the sustainability indicators. Each attribute has a total of 6 levels – 3 desirable and 3 undesirable attribute levels. The possible combinations of the different attribute levels make up the different options in a choice task. Figure 2 presents three examples of a choice task, each task representing different options for the three sustainability dimensions. In the survey questionnaire, the respondents were given 5 choice tasks (1 fixed task and 4 random tasks) for each of the sustainability dimensions. In each choice task the respondents were asked to choose only one among three options. The options are linked to a given type of biomass, which can be either first generation (i.e. sugar-rich crops, starch-rich crops and oil-rich crops) or second generation (i.e. agriculture/forest residues, fast-growing trees, and perennial grasses) bioenergy crops. We used the feedstock attribute levels as reference for each option so that the respondents can explicitly link their choice decisions to the types of biomass. In this way, we reduce the level of abstraction, which is a common problem in sustainability assessments. This conforms to the STRAP framework which assumes that sources of feedstock for bioenergy production influence the sustainable development in the sector (Acosta-Michlik et al. 2011). Only 3 options per task were presented to make it easier and faster for the respondents to make their choices. Moreover, while it is better to present more choice tasks to increase the sample size, we presented only 5 tasks per sustainability dimension to avoid overloading the respondents with information. Too much tasks could result in a decrease in survey completion rate, or confuse the respondents and make them respond superficially.

The SSIWeb Sawtooth software was used not only to analyse the responses of the respondents (i.e. compute utilities and preference weights), but also to construct the choice tasks and prepare the conjoint questionnaire. We use complete enumeration as a random tasks generation method and traditional full profile design. Moreover, the software package includes a statistical test (i.e. logit efficiency) to validate the survey design prior to its implementation. It is useful to validate the survey design to identify the optimal number of options and choice tasks as well as number of questionnaire versions that will yield statistically significant results for a given number of respondents. The different versions of the questionnaire have different sets of options and choice tasks, except for the fixed task, which is the same for all questionnaire versions. The validation results show relatively good fit for a survey design with 20 versions and 200 respondents. On the basis of these results, we aimed to survey a minimum of 200 respondents. We used the web-platform of the software to conduct the survey through the internet. The web link to the survey and a unique username were sent to the respondents per e-mail. The use of username ensures that each respondent complete the survey only once. For respondents who do not have access to internet, we converted the same survey into CAPI (Computer Aided Personal Interview) module, which refers to data collection using a laptop or a personal computer not connected to the internet.

Table 1 Economic, social and ecological sustainability attribute levels

Attribute levels	More desirable	Less desirable
Energy security		
1. Domestic energy demand	Low	High
2. Domestic energy supply	High	Low
3. Foreign energy trade	Low import	High export
Technology progress		
1. R&D investment	High	Low
2. Technology deployment	High	Low
3. Energy efficiency	High	Low
Market organisation		
1. Market incentives	High	Low
2. Market infrastructure	Good	Poor
3. Trade constraints	Low	High
Food security		
1. Food self-sufficiency	Increase	Decrease
2. Purchasing power	Increase	Decrease
3. Affordability of food	Increase	Decrease
Social welfare		
1. Livelihood sources	Increase	Decrease
2. Job opportunities	Increase	Decrease
3. Household lifestyle	Improve	Worsen
Social justice		
1. Equal property rights	Hinder	Support
2. Home displacement	Cause	Prevent
3. Land dispossession	Cause	Prevent
Production potential		
1. Potential level	Very high	Low
	High	Very low
	Moderate	No potential
2. Feedstock sources*	Crop/forest residues	Starch-rich crops
	Fast-growing trees	Sugar-rich crops
	Perennial grasses	Oil-rich crops
Resource capacity		
1. Effects of population pressure	Production potential unaffected	Production potential affected
2. Pressure on natural resources	Put less pressure	Put more pressure
3. Effects landscape and species diversity	Improve diversity	Destroy diversity
Land management		
1. Effects on nature conservation	Support	Conflict
2. Compatibility with organic farming	Compatible	Incompatible
3. Availability of good farming practices	Available	Not available

*Following the sustainability concept for bioenergy, first generation (i.e. food) crops are less desirable than second generation (non-food) crops as sources of feedstock for bioenergy production.

Figure 2 Examples of choice task in the conjoint survey on sustainability of bioenergy

In this part of the survey, we provide you different imaginary economic conditions to develop bioenergy production. Given these conditions, which type of biomass would you choose to produce bioenergy in order to support economic development in your country?

Please choose one option:

TYPES OF BIOMASS	Sugar-rich crops	Oil crops	Fast-growing trees
1. Energy security	Low domestic energy demand	High domestic energy demand	Low domestic energy supply
2. Technology progress	High R&D investment	Low R&D investment	High technology deployment
3. Market structure	High market incentives	Low market incentives	Good market infrastructure
	○	○	○

In this part of the survey, we provide you different imaginary social conditions that will result from bioenergy production. Given these conditions, which type of biomass would you choose to produce bioenergy in order to support social well-being in your country?

Please choose one option

TYPES OF BIOMASS	Starch-rich crops	Agriculture/Forest residues	Perennial grasses
1. Food security	Increase food self-sufficiency	Increase purchasing power	Increase affordability of food
2. Social welfare	Increase livelihood sources	Increase job opportunities	Improve household lifestyle
3. Social justice	Hinder equal property rights	Cause home displacement	Cause land dispossession
	○	○	○

In this part of the survey, we provide you different imaginary environmental conditions to develop bioenergy production. Given these conditions, which type of biomass would you choose to produce bioenergy in order to protect the environment in your country?

Please choose one option

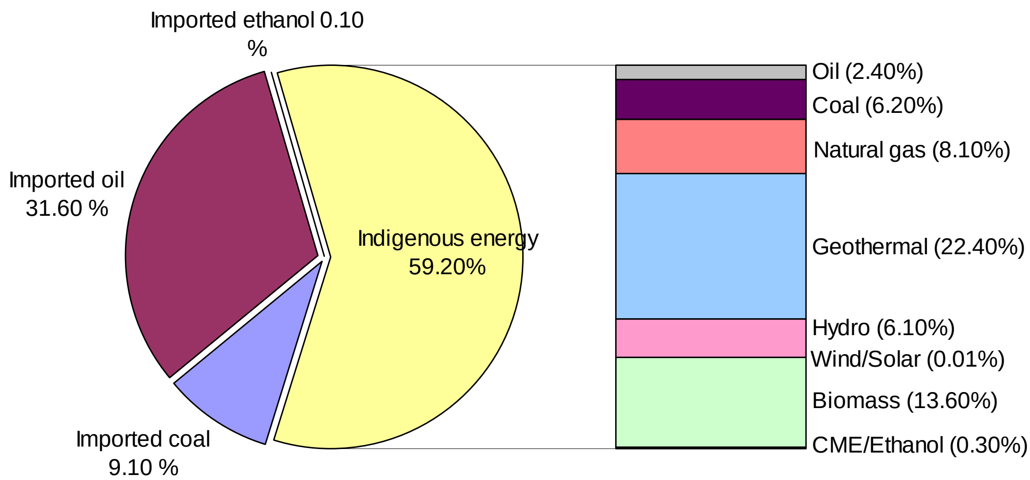
TYPES OF BIOMASS	Oil-rich crops	Fast-growing trees	Sugar-rich crops
1. Production potential	Very high potential	Moderate potential	Very low potential
2. Resource capacity	Potential affected by population pressure	Put more pressure on natural resources	Improve landscape and species diversity
3. Land management	Support nature conservation	Compatible with organic farming	Available good farming practices
	○	○	○

The survey was pre-tested in the field using the CAPI module, which enabled the interviewers to collect suggestions on how to improve the questionnaire. In addition to the choice tasks presented in Figure 2, the survey includes questions about the respondents' personal and employment background as well as opinion and general knowledge on the bioenergy sector. The location or field of work of the respondents were used as information for the conjoint segmentation. Specifically, the segments refer to five groups of respondents including (1) government officials and employees, (2) academic and research professionals, (3) private company managers and workers, (4) farm owners and workers, and (5) "others" (e.g. students, residents, etc.). The farmers were mainly surveyed using the CAPI module. The heads of the government institutions and private companies were contacted either in person or by telephone to get permission to send invitations to complete the WEB-survey. In most cases, they have provided the names and e-mail addresses of their colleagues and employees who were also invited to complete the survey. The respondents from the academic and research institutions were mainly derive from the authors' personal contacts and work colleagues, who in turn were requested to provide names and contacts of other people to be surveyed. The survey was conducted from April to June 2011. We sent out 312 WEB-surveys and carried out 53 CAPI-surveys.

3.3 The case study area

This paper assesses the trade-off decisions for society regarding sustainable bioenergy development in the Philippines. The Philippine economy has been growing at an average annual rate of 4.5 percent, with Gross Domestic Product (GDP) increasing from 918.2 to 1,432.0 billion Pesos from 1999 to 2009 (NSCB 2009). The average annual growth rate of the population was 2.1 percent, increasing from 74.7 million to 92.2 million for the same period. Despite the increase in GDP and population, energy demand in the Philippines was growing at an average annual rate of negative 0 .3 percent from 24.4 to 23.8 MTOE (i.e. Million Tons of Oil Equivalent) from 1999 to 2009 (DOE 2009). This negative growth is also reflected in the constant decline in energy, oil and electricity intensity over the same period. Energy intensity declined at an average annual rate of 4 percent, oil intensity 6.4 percent and electricity 0.4 percent. The declining trend in energy consumption and intensity has been mainly contributed to the decline in energy demand in residential applications and in agriculture, which showed an average annual growth rate of -2.8 and -2.1 percent, respectively. The continuing increase in the prices of petroleum prompted the consumers to utilize energy in more prudent ways (Salire 2007). After the transport sector (36.5 percent), the residential sector (26 percent) accounted for the largest share in total domestic energy demand. Whilst energy demand declined, energy supply continued to increase, albeit at a slow rate of 0.4 percent per year from 38.1 to 39.6 MTOE. The self-sufficiency level in energy increased from 48.6 percent in 1999 to 59.2 percent in 2009 as a result of the increase in indigenously supplied energy. Renewable energy such as geothermal energy and biomass are important indigenous sources of energy in the Philippines (Figure 3). The energy from biomass is mainly derived from forest and agriculture residues, and bagasse. However, the biomass is mainly used for household cooking, so there is a potential for increasing household welfare through improvement in the use of biomass (Samson et al. 2001).

Figure 3 Primary energy supply mix in the Philippines, 2009



Source: Department of Energy, Government of the Philippines

Like in many other countries, the Philippines is implementing various bioenergy policies to reduce dependence on imported oil, enhance economic growth, increase energy efficiency and contribute to climate change mitigation. The most prominent policy is the Biofuels Act of 2006, which mandates a 2 percent blend of biodiesel into all diesel fuel in 2008 and 10 percent blend of bioethanol into all gasoline fuel in 2010. The Act also allows oil companies to import biofuels until 2010 to meet these policy targets. Moreover, biomass for bioenergy production is exempted from value added tax and biofuel companies with 60 percent local ownership are provided financial assistance (Zhou and Thomson 2009). Whilst there were no reported obstacles during the transition to a higher biodiesel blend due to adequate local supply (Corpuz 2009), the bioethanol situation was less stable. To comply with the bioethanol mandates, local companies have been importing bioethanol due to supply scarcity and price volatility. In 2009 ethanol accounted for 0.30 percent of the total indigenous energy supply and 0.10 percent of the total domestic energy supply (Figure 3). Despite concerns about the impacts of importing bioethanol on local production, the government approved further imports in 2011 to meet its biofuel blending targets (DA-BAR 2011). The local supply of biodiesel and bioethanol is largely produced from coconut and sugarcane; both are traditional crops in the Philippines. Other potential biomass for bioenergy production includes jathropa for biodiesel, and cassava and sweet sorghum for bioethanol. The ethanol yields per hectare per year are 4,550 liters for sugarcane, 1,395 liters for cassava, and 6,000 liters for sweet sorghum (SRA 2008). The biodiesel yields per hectare are 630 liters for coconut and 1,892 liters for jatropha (DOE 2010). The government supports the production of jatropha for biodiesel because it is a non-staple crop and grows on marginal lands. Thus, the Philippines have the potential to develop a sustainable bioenergy sector using jatropha because this bioenergy crop does not compete with food crops and agricultural lands.

4 Results and discussion

4.1 Demographic profile and opinions of respondents

We received a total of 208 completed surveys, or a response rate of 57 percent. There were 25 incomplete surveys and 132 survey invitations with no response. The CAPI-surveys were mainly carried out in selected provinces (i.e. Batangas, Laguna, Quezon) in the Calabarzon region due to budget constraints. Although industry and urban areas in its two major cities (i.e. Batangas and Calamba) are expanding very fast, the Calabarzon region remains predominantly agriculture with its good soil quality and irrigation system. The WEB-surveys were sent to respondents in various agencies, companies and institutions in different regions in the Philippines. Figure 4 shows that there is almost an equal distribution of response rate for all the respondent groups. The highest number of responses was received from private companies accounting for 23 percent of the total survey, followed by the respondents from public agencies (22 percent). More than half of the respondents are less than 30 years old, many of them working in private companies (Table 2). Most of the respondents with an age between 31 and 70 are working on farms. Less than one percent of the respondents are older than 70 years old. In terms of level of education, more than 80 percent of the respondents have completed undergraduate and graduate studies. The majority of the respondents from public agencies and academe have graduate degrees. Those working on farms have mostly attained only up to secondary education. As for the location of their domiciles more than half of the respondents live in urban (i.e. city, industrial and commercial) areas, particularly those who are working in public agencies and private companies. Overall, there is almost an equal distribution in the gender of the respondents. Across the respondent groups, however, male dominates the respondents from both private companies and farms.

Figure 4 Distribution of survey response by group of respondents

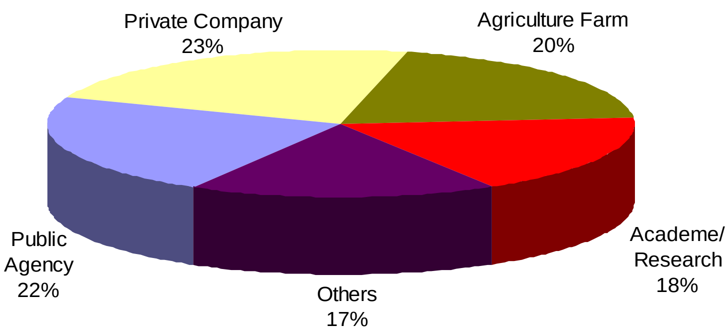


Table 2 Demographic characteristics of the respondents, in percent

Demographic Characteristics	Public Agency	Private Company	Agriculture/ Farm	Academe/ Research	Others	All Respondents
Age						
less than 30	11,54	18,27	2,88	13,46	13,94	60,10
between 31and 50	5,77	3,85	11,54	3,37	1,92	26,44
between 51 and 70	5,29	0,00	5,77	0,96	0,48	12,50
greater than 70	0,00	0,48	0,00	0,00	0,48	0,96
Education						
up to secondary	0,48	0,00	13,94	0,00	0,00	14,42
undergraduate	8,65	12,50	4,33	6,73	9,62	41,83
graduate	12,98	9,13	1,44	11,06	6,73	41,35
others	0,48	0,96	0,48	0,00	0,48	2,40
Gender (% female)						
male	11,06	13,94	15,87	9,13	5,29	55,29
female	11,54	8,65	4,33	8,65	11,54	44,71

Note: The values are percent of the total 208 respondents, thus the column "All Respondents" sum up to 100 percent for each demographic characteristic.

We asked the respondents if they are familiar with the term "bioenergy". About 86 percent of all the respondents answered "yes" (Table 3). The familiarity with bioenergy was lowest among the farmers accounting for only 9 percent, which is half the value for the other groups of respondents. On the question "Is your work related to bioenergy?", only 17 percent of all respondents answered "yes". Again, the farmers have the lowest positive answer to this question. In fact, none of the 42 surveyed farmers consider their work as related to bioenergy. The highest number of respondents whose work is related to bioenergy comes from public agencies and academe, mainly in bioenergy research/study and policy/program. Few of these respondents also chose the option "bioenergy crop production" as part of their work. However, none of the farmer respondents who are producing sugar and coconut, the most important feedstock for bioethanol and biodiesel production in the Philippines, chose this option. This implies that none of them has established either contact or contract with biofuel producers. On the question linking bioenergy and food security, half of all the respondents believe that the use of food crops for bioenergy production affects food security. The largest number of respondents with this opinion comes from public agencies. Despite the controversy on bioenergy and food security, almost all the respondents (92.35 percent) think that bioenergy is good for the Philippines. The respondents who think otherwise are mainly farmers. In the survey, we asked the respondents to rate the importance of the different sources of information on bioenergy. The most important sources of information are media (86 percent) and science (77 percent) particularly for the respondents from public agencies and private companies (Table 3). Family and neigbours are not very important sources of information. Except for the media, the farmers do not consider any of the given choices as a very important source of information for bioenergy. These results show that, although bioenergy is an important issue in policy and science, it has not yet become a very important concern for the farmers.

Table 3 Opinion of respondents and their most important source of information on bioenergy

	Public Agency	Private Company	Agriculture/ Farm	Academe/ Research	Others	All Respondents
Opinion on Bioenergy						
Familiar with the term bioenergy	22.12	20.67	9.13	17.79	16.83	86.54
Work is related to bioenergy	7.22	1.67	0.00	5.56	2.22	16.67
Bioenergy affects food security	15.87	9.62	8.17	9.13	8.17	50.96
Bioenergy is good for the country	22.40	22.95	9.29	19.13	18.58	92.35
Sources of information						
Media	15.85	17.49	8.20	12.02	12.57	66.12
Internet	13.11	15.85	1.09	10.38	9.29	49.73
Family	1.64	4.92	1.64	2.19	4.37	14.75
Neighbours	0.55	1.64	0.00	1.64	1.09	4.92
Colleagues	9.29	8.20	1.64	12.02	7.65	38.80
Public officials	10.93	12.02	1.64	10.93	8.20	43.72
Academe/Science	20.77	21.86	1.64	18.03	15.30	77.60
Business partners	1.94	11.61	0.65	6.45	3.23	23.87
Others	1.29	2.58	0.00	2.58	3.23	9.68

Note: The values are percent of the total 208 respondents. For the opinion on bioenergy, the respondents were asked to answer “yes” or “no”. The values presented in the table are only the percent of respondents who answered “yes”. For the sources of information, the respondents were asked to rate each source in terms of their importance – not important, least important, relatively important, and most important. The values presented in the table are only the percent of respondents who chose “most important”.

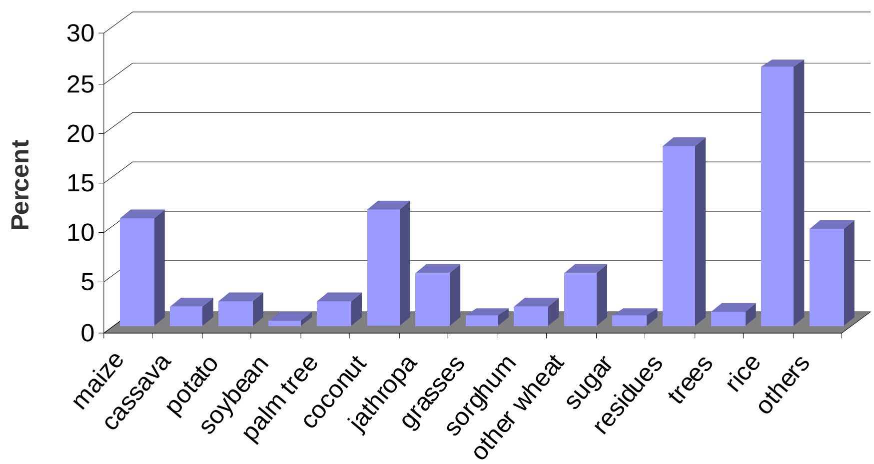
Table 4 presents the opinions of the respondents on the potential contribution of different energy sources to economic growth. Almost half of the total respondents think that bioenergy (46.63 percent) and other renewable sources (50.48 percent) have high potentials to support growth in the economy. Fossil energy alone is not considered to have as high a potential to contribute as renewable energies. However, if combined with renewable energies, many respondents, in particular those from government agencies and private companies, think that fossil energy can continue to have not only a high but also a very high contribution to economic growth. This opinion reflects the current energy mix in the Philippine energy sector with renewable sources like geothermal and biomass having an important share (Figure 3). However, a significant number of respondents do not have a particular opinion on the potentials of the different sources of energy (Table 4). A majority of the respondents who answered “do not know” are farmers. Moreover, the farmers are the least convinced that bioenergy could provide a very high contribution to economic growth. To investigate more thoroughly the respondents’ opinion on bioenergy, we also asked them to rate the potential contribution of the different biomass feedstock to economic growth. About half of the total respondents consider all first generation crops to have high potential to support economic growth, in particular oil-rich crops (Table 4). Among the second generation crops, agriculture and forest residues come closer to the first generation crops in terms of the number of respondents (45 percent) who thinks that this feedstock has high potential to support the Philippine economy. Most of these respondents are working in government agencies and private companies. As compared to first generation crops, there are more respondents (11-16 percent), mostly farmers, who answered “do not know” when asked if second generation crops have the potential to contribute to economic growth. Figure 5 shows that the work of the surveyed respondents is related to many crops, which are either currently used (i.e. sugar, coconut) or have the potentials (i.e. jathropa, sorghum, cassava) as biomass feedstock for bioenergy production in the Philippines. The respondents whose work is related to coconut (11 percent) and sugar (4 percent) are mainly farmers. Many of the farmer respondents also produce rice (16 percent), the crop residues of which are potential feedstock for modern biofuel. However, many of the farmers indicated that they are not aware of the potential contribution of both first and second generation crops to the Philippine economy.

Table 4 Opinions on the contribution of different energy sources and types of biomass

	Do not know	Very low	Low	High	Very high
Energy sources					
Fossil	8,65	6,73	25,00	35,58	24,04
Bioenergy	8,17	1,92	11,54	46,63	31,73
Other Renewables	11,54	2,40	11,06	50,48	24,52
Combined	10,58	0,48	12,50	37,98	38,46
Fisrt generation					
Sugar-rich crops	8,17	3,37	22,60	44,23	21,63
Starch-rich crops	7,69	5,29	24,52	43,75	18,75
Oil-rich crops	7,21	3,85	15,38	47,60	25,96
Second generation					
agriculture/forest residues	13,46	3,37	17,31	45,19	20,67
fast-growing trees	11,54	5,77	23,56	34,13	25,00
perennial grasses	16,35	7,21	29,33	35,10	12,02

Note: The values are percent of the total 208 respondents, thus each row sums up to 100 percent.

Figure 5 Crops related to the work of the respondents



4.2 Conjoint utilities and trade-offs of sustainability indicators

The logit estimates for the different attribute levels of the three sustainability dimensions are presented in Table 5 and the mean values of the utilities, which were used for the logit estimations, are given in Annex 1. The results, which show that the level of significance of the types of biomass varies across the sustainability dimensions, support the concept of the STRAP approach that the sustainability of bionergy production is influenced by the feedstock resources. For economic stability the results show that the respondents are willing to trade-off starch-rich crops and perennial grasses for agriculture/forest residues and fast-growing trees. The degree of willingness to use agriculture and forest residues for bioenergy is lowest among the farmers (Annex 1), which could be explained either by their lack of awareness of its potential contribution to the economy (see section 4.1) or by the importance of farm residues not only for organic farming but also for household cooking (see section 3.3). Starch-rich crops are least preferred by the respondents, which is not surprising because they are important staple food in the Philippines. For social equity only the estimates for sugar-rich crops and fast-growing trees are statistically significant. The respondents are very willing to trade off the former for other types of biomass, in particular fast-growing trees. For resource productivity the respondents have high preferences not only for fast-growing trees but also oil-rich crops (Table 5). The high utilities for oil-rich crops reflect the awareness among many respondents on the potential of coconut for bioenergy production in the Philippines. Among the first generation crops, oil-rich crops are generally preferred particularly among the respondents in academe to achieve not only sustainability in resource productivity but also social equity (Annex 1). Among the second generation crops, perennial grasses are not preferred due to a lack of awareness of many respondents (about 16 percent of total respondents) on the potential of these crops for bioenergy production (Table 4).

Many of the attribute levels representing the determinants and indicators for economic sustainability are not statistically significant (Table 5). In terms of the topic of energy security, except for energy supply, all attribute levels are not significant indicators to explain the respondents' preferences in the Philippines. On the one hand, the decreasing trend in energy demand reflects the insignificance of energy demand as an economic indicator (see section 3.3). And on the other hand, the relatively high level of energy self-sufficiency in renewable energy including biomass could explain the insignificance of international bioenergy trade as an indicator for achieving economic stability in the Philippines (see Figure 3). Moreover, import of biofuels from abroad is generally not supported due to its impacts on the development of the local bioenergy sector (DA-BAR 2011). The results imply that the respondents consider increasing domestic energy supply as the most relevant indicator, and thus the most preferred policy strategy for promoting economic growth. In terms of technology progress, the respondents are generally willing to trade-off other attribute levels for high R&D investment and high energy efficiency. The respondents not only from the public agencies and academic institutions but also the farmers have highest preferences for high R&D investments (Annex 1). In terms of market organization, the estimates of the attribute levels for market incentives and infrastructure are highly significant. The respondents are relatively more willing to trade-off for good market infrastructure than for high market incentives. Market incentives for bioenergy are already in place (albeit not sufficient), which explains why respondents, when given these two options, opt for better market infrastructure. During the CAPI-based survey, some respondents explained that the link between the feedstock producers and biofuel companies are not very well established. For example, some farmers who had been motivated by the government to plant jathropa did not find market for their feedstock. Moreover, bioethanol producers did not get sufficient feedstock when prices of sugar increased.

The attribute levels for social equity are all statistically significant except for the increase in purchasing power (Table 5). However, the decrease in purchasing power remained an important indicator for food security. The respondents are most willing to trade-off for the increase in affordability of food, followed by the increase in food self-sufficiency. In terms of social welfare, the willingness to trade-off between the different attribute levels is high particularly for the increase in job opportunities and increase in livelihood resources. The farmers and other group of respondents (i.e. students, residents) mostly prefer to exchange other attribute levels for the increase in job opportunities (Annex 1). Among the respondents, they have either less secure source of income or no employment. The farmers are most willing to trade-off worse household lifestyle for better employment and livelihood. This is because farmers and farm workers in the Philippines have usually low level of income and thus live a simple and mostly traditional lifestyle. In terms of social justice, bioenergy production that causes land dispossession is the least preferred condition as shown by the high negative estimate for this attribute level (Table 5). The farmers have particularly high negative utilities for land dispossession (Annex 1). Although land grabbing and buying for bioenergy production is not yet a common situation in the Philippines, Acosta-Michlik and Espaldon (2008) explain that multinational companies have easily bought agricultural land for agro-industrial businesses in the past. Many farmers sell their lands only reluctantly because farming is linked to family tradition.

Similar to social equity, almost all the attribute levels for resource productivity are statistically significant (Table 5). In terms of production potential, the respondents' are willing to trade-off for bioenergy crops with either high or very high potential. This particularly refers to fast-growing trees like jathropa and oil-rich crops like coconut, the utility estimates of which are both statistically significant (Table 5). Not surprisingly, the respondents do not support the use of crops with negligible or no potential for production. Although the productivity of sugar- and starch-rich crops for bioenergy production is high in the Philippines, they are generally traded-off for other crops to preclude competition between fuel and food use. As explained in section 4.1, half of the total respondents have the opinion that the use of food crops for bioenergy affects food security. In terms of resource capacity, the willingness to trade-off is highest for bioenergy crops that can help improve landscape and species diversity. Moreover, the respondents will support bioenergy only if its production will not put more pressure on the natural resources. The effects of population on bioenergy production are the least concern of the respondents, particularly those from academe (Annex 1). In terms of land management, the estimates of the attribute levels for nature conservation are very high (Table 5). Among the respondents, the farmers and other group of respondents (i.e. students, residents) have highest preference on bioenergy production that does not conflict with nature conservation. Moreover, most farmers also support bioenergy production that is compatible with organic farming. The use of agricultural residues will thus likely affect the availability of residues for organic farming. Whilst good farming practices are considered important for the sustainability of bioenergy production, the farmers' utilities for this attribute level are not particularly different from those of other respondents (Annex 1).

Table 5 Logit estimation results of the utilities for the different attribute levels of economic, social, and ecological sustainability

Economic Stability			Social Equity			Resource Productivity		
Attribute levels	Estimate (X_s)	t-ratio	Attribute levels	Estimate (X_s)	t-ratio	Attribute levels	Estimate (X_s)	t-ratio
Sugar-rich crops	-0.02	-0.21	Sugar-rich crops	-0.30***	-2.86	Sugar-rich crops	-0.25**	-2.40
Starch-rich crops	-0.32***	-3.29	Starch-rich crops	-0.08	-0.79	Starch-rich crops	-0.28**	-2.66
Oil crops	-0.04	-0.46	Oil-rich crops	0.15	1.54	Oil-rich crops	0.22**	2.34
Agriculture/Forest residues	0.36***	4.15	Agriculture/Forest residues	0.14	1.51	Agriculture/Forest residues	0.14	1.49
Fast-growing trees	0.27***	3.09	Fast-growing trees	0.20*	2.02	Fast-growing trees	0.32***	3.28
Perennial grasses	-0.25**	-2.62	Perennial grasses	-0.11	-1.14	Perennial grasses	0.16	-1.63
Low energy demand	-0.12	-1.32	Increase food self-sufficiency	0.36***	3.84	Very high potential	0.40***	4.37
High energy demand	0.15	1.67	Decrease food self-sufficiency	-0.51***	-4.67	High potential	0.59***	6.19
Low energy supply	-0.21**	-2.26	Increase purchasing power	0.13	1.33	Moderate potential	0.12	1.26
High energy supply	0.20**	2.20	Decrease purchasing power	-0.22**	-2.30	Low potential	-0.22**	-2.14
Low energy import abroad	-0.11	-1.19	Increase affordability of food	0.57***	6.17	Very low potential	-0.38***	-3.69
High energy export abroad	0.10	1.10	Decrease affordability of food	-0.32***	-3.08	No potential	-0.50***	-4.75
High R&D investment	0.21**	2.34	Increase livelihood sources	0.57***	6.23	Unaffected by population pressure	0.21**	2.21
Low R&D investment	-0.10	-1.01	Decrease livelihood sources	-0.31***	-2.99	Affected by population pressure	-0.11	-1.07
High technology deployment	-0.05	-0.59	Increase job opportunities	0.61***	6.79	Less pressure on resources	0.31***	3.35
Low technology deployment	-0.14	-1.52	Decrease job opportunities	-0.54***	-4.94	More pressure on resources	-0.43***	-4.01
High energy efficiency	0.19**	2.08	Improve household lifestyle	0.21**	2.19	Improve biodiversity	0.57***	5.95
Low energy efficiency	-0.11	-1.18	Worsen household lifestyle	-0.54***	-4.85	Destroy biodiversity	-0.56***	-5.31
High market incentives	0.36***	4.09	Hinder equal property rights	-0.23**	-2.23	Support nature conservation	0.61***	6.58
Low market incentives	-0.31***	-3.20	Support equal property rights	0.39***	4.33	Conflict with nature conservation	-0.71***	-6.16
Good market infrastructure	0.44***	5.14	Cause home displacement	-0.30***	-2.88	Compatible with organic farming	0.41***	4.48
Poor market infrastructure	-0.38***	-3.92	Prevent home displacement	0.35***	3.80	Incompatible with organic farming	-0.21*	-2.05
High trade constraints	-0.14	-1.50	Cause land dispossession	-0.45***	-4.26	Available good farm practices	0.30***	3.29
Low trade constraints	0.04	0.40	Prevent land dispossession	0.23**	2.35	Unavailable good farm practices	-0.40***	-3.75

Note: Asterisks indicate coefficients significantly different from zero at $\alpha = 0.01$. $\alpha = 0.05$. $\alpha = 0.10$, respectively. The utilities are measures of preferences where (1) utilities with positive values are preferred over those with negative values, and (2) for positive utilities, the larger the utility values the higher the preference level. The signs and values of the utilities together thus measure the respondents' willingness to trade-off less desirable attribute level for more desirable one.

4.3 Preference weights and importance of sustainability determinants

From the conjoint utilities of the attribute levels, we computed the preference weights of the attributes to gain an idea of the relative importance of the different determinants of sustainability. Figure 6 presents the distribution of the weights for all the respondents. In assessing the importance of economic stability for bioenergy sustainability, the respondents consider the types of biomass as the most important determinant, followed by market structure. Social welfare is the most important determinant for the social sustainability of bioenergy, whilst land management is the most important determinant for resource productivity. In the assessment of preference weights of economic stability by group of respondents, the variance between the groups are statistically insignificant except for market structure, albeit significant only at a 10 percent level (Table 6). The importance given to this attribute is highest among the respondents in academe and "other" group with preference weights of at least 30 percent. Hence, except for market structure, the opinions of the respondents on the relative importance of different economic determinants on bioenergy sustainability are relatively homogeneous. The diversity of opinions is more evident for the determinants of social equity. Except for food security, the mean squares of all the social determinants are statistically significant. The variance is largest for the types of biomass. For the farmers, the choice of biomass feedstock (29 percent) is the most important determinant for ensuring social sustainability of bioenergy. Social justice is the least important determinant for social equity among the farmers. Among the determinants of resource productivity, the only statistically insignificant mean square is for resource capacity. Like in social equity, the types of biomass have the largest diversity of opinion in resource productivity. The farmers also consider the types of biomass as the most important determinant for achieving ecological sustainability. However, the farmers have the lowest preference weights for production potential (22.67 percent) and land management (25.66 percent). These results reveal that when it comes to the role of resource productivity in bioenergy sustainability, the farmers have very different opinions from the rest of the respondents.

Figure 6 Distribution of preference weights among the different sustainability attributes

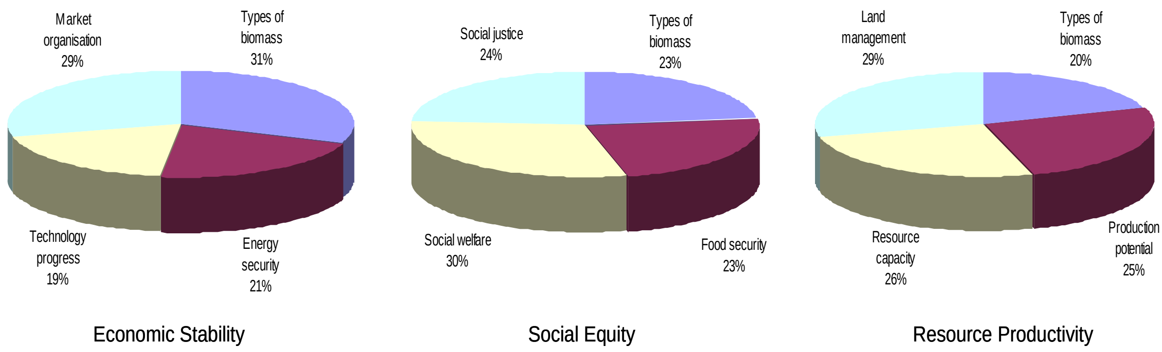


Table 6 Average preference weights of the different sustainability attributes, by respondents

Attributes	Respondent groups: Public Agency	Private Company	Agriculture/ Farm	Academe/ Research	Others	Mean Squares	Statistical Significance
Economic Stability							
Type of biomass	33.46 (12.67)	30.21 (12.28)	32.36 (10.16)	28.77 (10.94)	28.10 (9.52)	214.99	0.16
Energy security	20.06 (6.38)	21.36 (6.09)	21.68 (6.59)	21.84 (6.19)	20.77 (5.92)	23.22	0.67
Technology progress	18.76 (5.27)	18.91 (5.62)	19.77 (5.94)	19.35 (5.07)	19.66 (5.29)	8.53	0.89
Market structure	27.72 (10.01)	29.53 (9.13)	26.19 (8.55)	30.04 (8.70)	31.47 (9.18)	168.11	0.10
Social Equity							
Type of biomass	23.27 (8.73)	20.42 (9.05)	29.77 (8.99)	20.21 (9.01)	20.97 (8.40)	668.54	0.00
Food security	22.93 (4.71)	23.10 (4.34)	23.10 (4.04)	22.89 (3.97)	23.94 (4.11)	6.64	0.83
Social welfare	29.49 (6.60)	31.97 (6.36)	26.15 (7.53)	31.61 (5.99)	31.17 (5.84)	240.24	0.00
Social justice	24.31 (5.71)	24.51 (5.44)	20.98 (5.38)	25.29 (4.63)	23.92 (6.14)	113.40	0.01
Resource productivity							
Type of biomass	19.41 (10.12)	17.83 (10.89)	25.83 (11.10)	17.32 (7.86)	18.19 (7.96)	509.05	0.00
Production potential	25.57 (5.56)	26.00 (6.36)	22.67 (6.32)	27.19 (5.89)	26.11 (6.00)	116.67	0.01
Resource capacity	26.50 (4.43)	25.83 (4.42)	25.84 (5.45)	25.97 (5.55)	25.75 (4.79)	4.06	0.95
Land management	28.53 (6.36)	30.33 (5.58)	25.66 (7.12)	29.52 (5.54)	29.95 (4.97)	148.17	0.00

Note: The preference weights (ω_{ij}) are in percent and the numbers in parenthesis are its standard deviation.

5 Conclusions

In this paper, we conducted a survey with five groups of respondents including (1) government officials and employees, (2) academic and research professionals, (3) private company managers and workers, (4) farm owners and workers, and (5) "others" (e.g. students, residents, etc.) to assess their trade-off decisions on bioenergy development in the Philippines. Both descriptive and statistical (i.e. conjoint or choice model) analyses were applied to the 208 completed survey results, which reveal that balanced sustainability of bioenergy production depends on the choice of biomass feedstock and these choices depend on people's perceptions. These perceptions are in turn influenced by profession, awareness, and experience. The respondents from the government, academe and companies whose work are either directly or indirectly related to bioenergy are well informed about the sustainability issues related to bionergy production. The flow of knowledge and information between policy and science, and to some extent business (i.e. private company), either through work relations or media contributes to a more or less common perception and thus awareness of the sustainability problem of bioenergy among these respondents. However, the farmers remain disconnected from this information network due to their lack of interactions with policy, science and business. Unlike in other agricultural sector, outreach programs and activities, for example, through government extension programs, research experiments and investigation, and agri-business contracts are still very much needed for bioenergy. This will improve the level of awareness among the farmers, who in general have a lower level of education. On the one hand, farmers' awareness of the potential contribution of feedstock, in particular from second generation crops, are crucial to the economic sustainability of the bioenergy sector. Farmers play an important role in producing the needed raw materials for bioenergy production and, as the results show, they give very high importance to the types of biomass when assessing bioenergy sustainability. On the other hand, farmers' experience on agricultural production can inform policy and science on appropriate farm practices and management to ensure ecological sustainability of bionergy production. The results show that compared to other respondents, the farmers give more importance to nature conservation and organic farming as important indicators for resource productivity. Moreover, past experiences of the farmers on the taking over of their lands by agro-industrial investors can be useful for designing a policy to regulate land use for bioenergy and to prevent land dispossessions. Like in many developing countries with high potential for bioenergy production, such policy is also crucial for the social sustainability of bioenergy production in the Philippines.

The diversity of opinions on the appropriate bioenergy feedstock to achieve economic, social and ecological sustainability suggests that sustainability of bioenergy is not a generic concept. The results show that when people are asked about their opinions on the potential contribution of different biomass to economic growth, they generally think that either first or second generation crops have high potential contributions. However, as soon as their choice decisions are linked to a set of not only economic but also social and ecological conditions, people's perceptions vary according to the types of biomass. Scientific analysis provides a much-needed basis for the deployment of bionenergy in a manner that avoids detrimental effects wherever possible. However, without taking the preferences and perceptions of the population into account, deployment will not be successful in an open society, and the required synergies between groups will not be achieved. Some aspects of bioenergy deployment cannot be decided scientifically therefore the choices of people living on the land have to be considered. In the case of the Philippines, whilst people are generally convinced about the economic sustainability of bioenergy, there are remaining social and ecological concerns that need attention in order to identify the appropriate biomass feedstock for a sustainable bionergy development. The use of aggregate indices for sustainability assessments that ignore these perceptions on bioenergy production can thus be very misleading. The results of this paper can help improve sustainability indices by integrating information on conjoint preference weights, which measure human preferences on different determinants and indicators of economic, social and ecological sustainability. The application of these preference weights for developing sustainability indices is beyond the focus of this paper.

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Annex 1 Average utilities for the attribute levels of the sustainability dimensions, by respondents

Attributes	Public Agency	Private Company	Agriculture/ Farm	Academe/ Research	Others	All Respondents
Economic Stability						
Types of biomass						
Sugar-rich crops	-20.50	-11.40	-1.47	-0.66	6.05	-6.61
Starch-rich crops	-33.24	-29.05	-24.61	-19.70	-10.60	-24.33
Oil crops	-12.99	-12.99	11.64	3.26	-10.70	-4.74
Agriculture/Forest residues	51.05	36.67	23.02	29.35	31.72	35.03
Fast-growing trees	39.37	34.59	14.45	10.20	3.23	21.99
Perennial grasses	-23.70	-17.81	-23.03	-22.45	-19.71	-21.34
Energy security						
Low domestic energy demand	-9.67	-2.93	-7.91	-9.35	-17.83	-9.11
High domestic energy demand	5.70	20.91	14.69	17.29	10.53	13.83
Low domestic energy supply	-14.76	-23.60	-25.80	-27.78	-11.01	-20.67
High domestic energy supply	22.13	26.51	22.68	26.11	24.18	24.28
Low energy import abroad	-2.30	-16.46	-1.00	-10.75	-9.28	-7.91
High energy export abroad	-1.10	-4.42	-2.66	4.48	3.41	-0.42
Technology progress						
High R&D investment	23.89	18.69	24.23	23.65	15.66	21.36
Low R&D investment	-17.83	-18.54	-9.96	-14.67	-11.04	-14.70
High technology deployment	-7.15	-2.65	-4.83	-3.06	-9.05	-5.26
Low technology deployment	-3.41	-8.32	-10.46	-10.50	-5.11	-7.49
High energy efficiency	13.18	21.51	15.65	19.58	25.23	18.73
Low energy efficiency	-8.68	-10.70	-14.63	-14.98	-15.69	-12.64
Market organisation						
High market incentives	30.88	31.99	27.68	35.86	40.69	33.02
Low market incentives	-22.30	-31.10	-29.14	-33.00	-39.29	-30.43
Good market infrastructure	36.83	56.68	32.44	45.38	49.87	44.14
Poor market infrastructure	-35.39	-46.75	-35.00	-41.94	-46.37	-40.89
High trade constraints	-20.33	-11.18	-0.28	-10.83	-4.27	-9.82
Low trade constraints	10.31	0.36	4.29	4.54	-0.63	3.98
Social equity						
Types of biomass						
Sugar-rich crops	-18.97	-24.99	-21.62	-13.69	-14.97	-17.89
Starch-rich crops	-3.40	-7.70	-2.78	-4.90	4.11	-4.60
Oil-rich crops	3.65	-3.40	-1.31	31.25	-7.16	-1.91
Agriculture/Forest residues	16.78	24.29	18.90	-4.09	21.19	24.25
Fast-growing trees	3.42	10.12	7.74	-4.92	-1.59	3.92
Perennial grasses	-1.48	1.67	-0.93	-3.65	-1.58	-3.76
Food security						
Increase food self-sufficiency	18.62	18.43	23.85	3.37	25.66	22.71
Decrease food self-sufficiency	-36.23	-37.48	-38.92	-30.72	-37.74	-35.96
Increase purchasing power	17.59	19.29	21.92	5.57	22.60	18.60
Decrease purchasing power	-16.99	-21.01	-20.84	-3.22	-21.68	-18.00
Increase affordability of food	44.03	44.49	42.27	46.47	42.17	44.83
Decrease affordability of food	-27.02	-23.72	-28.28	-21.46	-31.03	-32.18
Social welfare						
Increase livelihood sources	39.74	39.86	43.59	32.05	42.34	40.89
Decrease livelihood sources	-14.95	-16.29	-22.14	-3.71	-17.43	-14.38
Increase job opportunities	47.33	46.11	58.28	25.90	57.69	49.04

Decrease job opportunities	-48.82	-48.43	-51.81	-36.53	-54.02	-54.60
Improve household lifestyle	21.29	23.19	22.51	16.54	19.79	24.40
Worsen household lifestyle	-44.59	-44.44	-50.43	-34.24	-48.37	-45.37
Social justice						
Hinder equal property rights	-20.71	-24.97	-23.36	-20.12	-16.58	-16.52
Support equal property rights	27.47	31.45	32.44	9.21	32.20	32.39
Cause home displacement	-13.98	-12.14	-8.90	-16.52	-15.76	-18.33
Prevent home displacement	27.76	29.84	31.21	19.34	30.55	27.48
Cause land dispossession	-37.15	-41.66	-46.53	-8.63	-47.53	-41.76
Prevent land dispossession	16.61	17.49	15.13	16.72	17.11	16.75
Social equity						
Types of biomass						
Sugar-rich crops	-12,96	-13,96	-14,32	-9,94	-13,96	-12,35
Starch-rich crops	-21,11	-25,94	-22,06	-19,93	-20,04	-15,91
Oil-rich crops	12,00	9,24	8,57	31,25	5,02	4,60
Agriculture/Forest residues	14,02	14,95	14,07	12,77	12,52	15,79
Fast-growing trees	21,01	25,56	22,05	12,13	22,17	22,91
Perennial grasses	-12,95	-9,85	-8,31	-26,27	-5,71	-15,03
Production potential						
Very high potential	30,14	28,70	33,60	20,15	38,12	30,99
High potential	37,16	37,75	41,33	23,29	44,35	39,81
Moderate potential	10,83	12,07	11,51	4,49	14,48	11,99
Low potential	-15,74	-16,16	-14,01	-16,57	-17,81	-14,30
Very low potential	-20,33	-18,62	-22,15	-13,72	-24,85	-23,35
No potential	-42,06	-43,73	-50,28	-17,64	-54,30	-45,13
Resource capacity						
Affected by population pressure	-3,86	-2,68	-8,16	2,08	-5,54	-5,01
Unaffected by population pressure	9,72	15,58	14,41	-1,80	17,07	1,62
Put more pressure on resources	-29,42	-35,35	-29,86	-28,70	-30,62	-20,44
Put less pressure on resources	23,63	22,43	28,41	15,10	28,42	24,02
Improve biodiversity	39,94	41,62	39,91	37,23	42,37	38,40
Destroy biodiversity	-40,02	-41,61	-44,71	-23,91	-51,70	-38,58
Land management						
Support nature conservation	47,40	47,24	52,72	34,09	54,58	48,86
Conflict with nature conservation	-51,18	-51,66	-58,67	-38,35	-56,86	-49,88
Compatible with organic farming	26,16	26,40	31,82	17,65	27,85	26,66
Incompatible with organic farming	-13,81	-16,42	-18,07	-1,99	-18,19	-14,13
Available good farming practices	26,02	27,13	27,82	20,79	28,86	25,37
Unavailable good farming practices	-34,59	-32,69	-35,62	-32,19	-36,24	-36,89

Note: The utility values were computed using zero-centered difference as rescaling method (Orme 2006). In each attribute, the values of the utilities for all 6 levels thus sum up to zero. The utilities are measures of preferences where (1) utilities with positive values are preferred over those with negative values, and (2) for positive utilities, the larger the utility values the higher the preference level. The signs and values of the utilities together thus measure the respondents' willingness to trade-off less desirable attribute level for more desirable ones.

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