THREE ESSAYS EVALUATING TRADEOFFS IN AGRICULTURAL DECISION MAKING

Michael J. Barrowclough

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Jeffrey R. Alwang, Chair
Kathryn A. Boys
Leighton L. Geyer
Stephen K. Stephenson

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Abstract

The act of decision making involves a choice amongst tradeoffs. In agriculture this is no different. This dissertation is composed of four papers that examine the tradeoffs being made across different agricultural decision making processses. The first two papers examine the tradeoffs made at the individual producer level while the last two papers examine tradeoffs made at the national policy level.

The first paper investigates the tradeoffs that producers in two communities of Bolivar province, Ecuador, are willing to make when given the choice to adopt a hypothetical set of production practices referred to as "conservation agriculture". The aim of this paper was to add to the limited literature on how poor producers view production attributes associated with these types of practices and to provide insights into their potential use in marginal, steeply sloped, small-scale production systems.

The second paper uses a choice experiment approach to examine the preferences of small-scale specialty crop producers who are currently or are considering marketing their products into wholesale food markets. Producers in Virginia and North Carolina are specifically targeted. Key contract characteristics and buyer attributes are identified and producers' willingness to trade amongst these characteristics and attributes are measured.

The goal of the third and fourth papers was to look at the potential effects of biofuel production with respect to domestic nutrient production. Both papers examined the demands placed on domestic nutrient production along with cropland from biofuel production since the implementation of the 'Renewable Fuel Standard' in 2006. A simple and direct approach was taken in both papers and can easily be extended to examine most any type of biofuel production coming from agricular crop production.

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General Audience Abstract

The act of decision making involves a choice amongst tradeoffs. In agriculture this is no different. This dissertation is composed of four papers that examine the tradeoffs being made across different agricultural decision making processses. The first two papers examine the tradeoffs made at the individual producer level while the last two papers examine tradeoffs made at the national policy level.

The first paper investigates farmer attitudes towards how a hypothetical set of production practices referred to as "conservation agriculture" will affect yield, labor use, erosion, and cost in two communities of Bolivar province, Ecuador. By evaluating the tradeoffs producers are willing to make when choosing to adopt such practices, changes in producer welfare associated with adoption may be identified. These measures can assist in identifying constraints to adoption and aid in extension and policy outreach development.

The second paper aims to gain a better understanding of the dynamic relationship between farmers and food buyers. This issue is examined from the perspective of small-scale specialty crop producers who are currently or are considering marketing their products into wholesale food markets. With a focus on farms in Virginia and North Carolina, this study seeks to identify key contract characteristics and buyer attributes which are valued by small-scale specialty crop producers; quantify tradeoffs small-scale specialty crop producers are willing to make between buyer attributes and contract characteristics when establishing a new contractual relationship; and determine the factors influencing these tradeoffs.

The third and fourth papers examine the demands that U.S. biofuel production has placed on domestic nutrient fertilizer production. A key argument in favor of domestic biofuel production is that it is a renewable path towards energy independence. However the inputs used in the production of biofuel feedstock, primarily fertilizer nutrients, are anything but renewable. These two papers add to the discussion surrounding biofuel policies by asking an important question that has not received the attention it deserves: "What about the non-renewable inputs (e.g., nutrient fertilizers) that go into producing the inputs (e.g., corn) used for biofuel production?"

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I would like to thank my wife and best friend, Jenny, for the countless sacrifices she has made in helping me achieve this goal. I would also like to thank Jeffrey Alwang, Leon Geyer, Kathryn Boys, and Kurt Stephenson for all of their guidance and support.

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1 Conservation Agriculture in Ecuador's Highlands: A Discrete Choice Experiment

1.1 Introduction

Small-scale farmers in marginal areas of developing countries earn meager incomes and tend to be poor. Their farming practices often cause environmental damage from soil erosion and depletion of soil health. Relatively new techniques, such as conservation agriculture (CA), have the potential to reduce and even reverse soil degradation in such areas. However, there are ongoing questions about the appropriateness of CA for small-scale farming as poor farmers tend to be risk averse, typically lack access to credit, and may have planning horizons associated with heavily discounted future benefits.

Conservation agriculture has successfully spread in a number of developing-country contexts, resulting in both positive production and environmental impacts. In India, minimum-tillage reduced labor use by 30% (Lai et al., 2012). Maize yields in Mexico doubled under CA compared to conventional practices (Govaerts et al., 2005). In Paraguay, no-tillage decreased erosion from 21.4 tons ha^{-1} to 0.6 tons ha^{-1} (Saturnino and Landers, 1997). In Brazil, no-till methods for a soybean-corn rotation increased soil carbon by 6.2% (Bayer et al., 2006).

While CA can potentially benefit farmers and have broad social benefits such as reduced off-farm damages from erosion and increased carbon sequestration, barriers to its adoption exist. Lack of information about CA methods, risks associated with adopting new practices, limited availability of credit, and the inability of farmers to capture the full social and environmental benefits from CA all reduce the likelihood of its adoption. Since benefits accrued from CA may not emerge immediately, farmers may be reluctant to adopt due to high upfront costs and uncertainty about long-term benefits. Differences in the long-term flow of costs compared to benefits can lead to varying CA acceptance. In many developing countries, where near-subsistence agriculture predominates, CA practices may have potential, but adoption has been slow. A possible reason for this is the specificity of the crops grown in a particular region and the lack of information on how CA impacts those crops. While CA practices for maize production have been extensively studied and results made widely known, the same cannot be said about less common crops, such as those limited to a specific region in a developing country (Giller et al., 2009).

One country where CA has promise is Ecuador. In Ecuador's highlands, farming on steep slopes is associated with high soil erosion and gradually declining productivity (SANREM, 2013). Highland producers face problems of labor shortages, low returns, erratic weather, and lack of credit (Barrera et al., 2010). Landholding sizes are small and shrinking due to sub-division of family farms; shrinking farm sizes lead to incursions into fragile upland areas where intensive agricultural production can increase environmental damage. Conservation agriculture is a potential solution to these challenges, but has yet to spread widely in this area.

This study investigates farmer perceptions of CA attributes in two sub-watersheds in Bolivar province, Ecuador. In both communities, agriculture is the primary occupation with a large population of farm families producing at near-subsistence levels. Outreach efforts are needed to promote CA and the outreach messages should be structured around factors farmers value. To better understand the receptiveness of area farmers to CA, three objectives are addressed: (1) *identify factors affecting likelihood of adopting CA*; (2)

determine the relative importance of specific CA attributes to producers; and (3) *estimate expected welfare changes associated with adoption*.

A discrete choice experiment (DCE) is used to achieve these objectives. The DCE is estimated using a Random Parameter Logit (RPL) model, allowing for individual heterogeneity in preferences. Because production methods and input demands from CA practices likely differ from current production processes, growers' assessments of the probable changes associated with CA adoption are evaluated. Attitudes towards how a hypothetical set of CA production practices will affect yield, labor use, erosion, and cost of implementation are examined. Measurement of values farmers place on each of these attributes will help quantify the importance of the constraints to adoption identified above. Results show producers are most concerned with future yields, planting labor, and overall costs. While off-farm erosion impacts are of concern, producers only placed small values on these impacts. Results provide support for CA outreach to highlight practices that increase long-run production and reduce the time and technical skills associated with planting. As anticipated, substantial preference heterogeneity was evident, complicating the policy development design.

This paper adds to the limited literature on attitudes of developing country farmers towards agricultural production attributes. To the authors' knowledge, this is the first DCE conducted in Ecuador examining producer attitudes towards CA and, more generally, farming practices and their relationship to environmental outcomes. In Ecuador and other developing countries, public sector support to farmers is limited. Understanding factors motivating CA adoption can assist these limited outreach efforts in more efficiently aiding farmers sustain soil quality and raise output.

1.2 Conservation Agriculture

Conservation agriculture grew out of the conservation tillage movement, which began as an effort to combat the negative effects of soil erosion caused by conventional farming. Key differences between CA and conventional methods are the selection of crops, the treatment of the soil before planting, and how crop residue is treated after harvest. The three CA principles are: 1) *Minimal Soil Disturbance*, accomplished through either reduced-tillage, minimum-tillage, or no-tillage; 2) *Permanent Soil Cover*, by applying cover crops, plant residues, or mulch along with the crop itself; and 3) *Crop Rotations*, which requires the planting of specific crop types following a predetermined order (FAO, 2006). Practices following these three principles contribute to soil health and productivity over time via decreases in erosion rates and nutrient depletion, allowing for sustained increase in soil organic material and nutrients.

Considerable research has been conducted on the viability and profitability of CA in the study area. A joint research project between Ecuador's Instituto Nacional Autónomo de Investigaciones Agropecuarias (INIAP) and USAID has investigated CA for potato-based and maize-bean systems through experiments on farmer fields in both project sub-watersheds. The research shows that CA can be a profitable option for producers (SANREM, 2013).

A difficulty in advancing new agricultural practices such as CA among resource poor farmers is cost of adoption and risk and uncertainty. In rural areas of developing countries, credit markets often do not function well, and credit constraints, together with limited liquid assets can stifle adoption of CA (Jack, 2013). The constraint manifests itself in two possible ways: inability to purchase necessary equipment, or a requirement that the technology provide immediate returns. Practices that demand low upfront labor and purchased inputs, coupled with a quick and positive return are likely to be more acceptable to such farmers.

Short run benefits from CA adoption can be more indirect and less tangible for farmers compared to other agricultural innovations. The goal of CA is to build soil organic matter and improve soil health and productivity. To do this, some short-term "sacrifices" such as lost productivity may be experienced (Giller et al., 2009). Therefore CA may best promoted through the lens of a long run planning horizon. When multiple CA practices are used in conjunction with one another, increased benefits can be more speedily realized.

1.3 Study Site

Farmers in the Illangama and Alumbre watersheds of Bolivar province have small steeply sloped landholdings of relatively low productivity. The Illangama watershed is located between 2,800 – 5,000 meters above sea level (masl) and covers 130km^2. Potato and dairy are the principal farming activities. Other crops include quinoa, barley, wheat, melloco, and faba beans. The Alumbre watershed is approximately half the size of the Illangama and is located between 2,000 – 2,800 masl. Maize and beans are the major crops, and others include peas, wheat, and Andean fruit. Agriculture is the primary source of income in both watersheds and farmers are representative of growers throughout the region.

1.4 Conceptual Framework

Currently, with few CA practices being used in the study area, data on use of CA practices and revealed preferences towards them is lacking. Under these circumstances, it is only possible to evaluate stated preferences. Assuming producers would choose to implement an agricultural practice among a set of available practices that maximizes their utility, a random utility framework is applied following McFadden (1974). Adding to this Lancaster's (1966) consumer theory, utility from the chosen agricultural practice can be allocated to the attributes making up the practice. Producer utility can be represented as:

$$U_{ij} = V\left(X_{ij}, H_i\right) + \varepsilon_{ij} \tag{1}$$

where U_{ij} is the utility of producer *i* for agricultural practice *j* $(j \in J)$. Because utility cannot be observed, U_{ij} is partitioned into two additively separable components: $V\left(X_{ij}, H_i\right)$, a deterministic component comprised of the attributes of the agricultural practice, X_{ij}, and the characteristics of the producer, H_i; and a stochastic (random) element, ε_{ij}. Uncertainty regarding the utility level leads the decision analysis to become one of probabilistic choice (Bateman et al., 2002):

$$P_{ij} = \mathrm{Prob}\left(U_{ij} > U_{ik} \forall j \neq k \text{ and } j, k \in J\right). \tag{2}$$

Discrete choice experiments are a stated preference technique that follows this utility framework. DCEs have increasingly been implemented in developing countries to analyze topics such as health policy, the value of biodiversity, and environmental conservation and economic development tradeoffs (Hanson et al., 2005; Bennet and Birol, 2010; Cerda et al., 2013).

1.5 Methods and Data

A listing exercise identified 709 producers from 19 communities in Alumbre and 244 producers from 9 communities in Illangama. An initial target of 225 grower interviews with proportional coverage across both watersheds and individual communities was set. Participating farmers were randomly selected, first weighting for differences across watershed populations followed by individual community populations. In circumstances where growers were not home and unable to be interviewed, a nearest neighbor approach was used.

Interviews were conducted face-to-face over a three-week period in June 2013. The interview consisted of four sections: 1) socioeconomic and farm production characteristics, along with the description of four CA practices – contour cropping, reduced tillage, cover cropping, and crop rotation – and their current knowledge of each; 2) an explanation of the DCE and description of each choice attribute and its respective levels; 3) the DCE; and 4) an exercise assessing producers' attitudes towards risk. Six undergraduate students from Virginia Tech (USA), fluent in Spanish, conducted the interviews. INIAP researchers were also used as enumerators to ensure respondents understood what was being asked in the interview, specifically the DCE, and that social and cultural norms were conformed to.

A total of 233 interviews were conducted accounting for 24.4% of the farming population; in Alumbre 21.2% (150 interviews) of the farming population was interviewed along with 34.0% (83 interviews) from the Illangama watershed. Randomly selected farmers from the listing exercise made up 55.3% of the interviews with the nearest neighbor of selected but absent farmers accounting for the remaining 44.7%. With many growers farming on multiple lots not adjacent to one another, this high rate of absence was anticipated. Due to both time and costs constraints surrounding the data collection process, the use of the nearest neighbor approach was necessary. Thirteen growers declined participation, nine from Illangama and four from Alumbre. Summary statistics are presented in Tables 1.1 and 1.2. Interviewees had similar characteristics to other farmers in the area (Andrade, 2008).

[Insert Table 1.1 Here]

[Insert Table 1.2 Here]

1.5.1 Risk Attitudes Assessment

Agriculture is the primary source of income. It is therefore reasonable to assume any additional risks (real or otherwise perceived) incurred from implementing a new agricultural practice will influence adoption. Expanding on Barsky et al. (1997), a risk assessment scenario asking respondents to make hypothetical gambles over their lifetime income was conducted (Figure A.1). Responses suggest producers are willing to accept risk, with Illangama producers being more risk tolerant compared to those in Alumbre (see Table 1.1). The pattern of differences is reflected in the two extreme "gambling" scenarios. One percent (1 response) of Illangama respondents compared to over 10% of Alumbre were unwilling to accept any gamble (or risk) while nearly 50% of Illangama respondents accepted every gamble, compared to just over 25% for Alumbre. Following Hanna et al. (2001) relative risk aversion values were estimated for each watershed, with Alumbre and Illangama producers each having a risk aversion equal to 4.50 and 2.22 respectively. This equates to approximately 17.5% and 30% of income willing to be risked by Alumbre and Illangama producers, respectively, for a 50-50 chance at doubling their current income. Environmentally, Alumbre is much more degraded and farmers there might be expected to be less tolerant of risk. In addition, producers in Alumbre receive little income from non-farm activities and may therefore be less willing to risk the limited income that they currently collect.

1.5.2 Discrete Choice Experiment

Use of the DCE technique requires identification of attributes and the levels these attributes can take. In the case of CA among near-subsistence farmers, careful consideration of the attributes was necessary. Cultural differences, differences in perceptions, and differences in constraints could all affect valuation of factors associated with CA.

Identifying factors farmers value associated with adopting CA practices was completed via an extended two-phased process. The first phase consisted of compiling an extensive list of possible production attributes following a thorough examination of the literature. The literature review covered developed and developing country experiences. This literature identified several CA attributes affecting farmer perceptions of the viability of these practices: cost, productivity gains, technological demands, contribution to carbon sequestration, risk, credit availability, input demands, pests and disease, off-farm water quality, and labor changes (Govaerts et al., 2005; Pretty et al., 2006; Dumanski et al., 2006; Friedrich and Kienzle, 2007; Knowler and Bradshaw, 2007; Bond et al., 2011; Thierfelder and Wall, 2012; Jack, 2013).

The second phase involved agricultural researchers at INIAP using this compiled list in structured interviews with study area producers. These interviews occurred during regularly scheduled meetings with producer and community groups, training events such as farmer field days and workshops, and while conducting ongoing CA research in the area. Producers identified concerns about lack of adequate labor and increased labor costs. Producers blamed inconsistent weather and rainfall patterns along with pests and disease for yield variability. They also cited unpredictable market prices as a major source of risk.

This two-step process coupled with INIAP's regular interaction in the watersheds helped identify six attributes important to the adoption decision. These were: (1) *Four Year Yield*, (2) *One Year Yield*, (3) *Planting Labor Days*, 4) *Weeding Labor Days*, 5) *Soil Erosion* and 6) *Cost* (Table 3). These attributes reflect potential changes compared to conventional practices that may occur following CA adoption.

[Insert Table 1.3 Here]

On-farm trials in both sub-watersheds focused on four CA practices: *Contour Cropping*, *Reduced Tillage*, *Cover Crop*, and *Crop Rotation*[1]. Designed for farming on sloped fields, contour cropping involves planting crops along the land's contour. By following the slope, water flow is slowed, reducing erosion, increasing water retention, and leading to greater soil quality over time. Drawbacks include extra preparation time to determine the planting path along with additional "costs" from production area lost, as rows may no longer be in straight lines and equal distance apart. Reduced tillage can eliminate tilling an entire field and lead to significant savings in planting labor. Tillage reductions can increase weed growth, requiring higher weeding labor and herbicide use. Cover crops are crops planted directly after harvest, where residue cover is maintained protecting the soil from wind and water erosion, helping to suppress weed growth, and increasing soil organic matter and residual moisture. Extra costs are incurred however, such as the time and labor to plant and harvest (or kill off) the additional crop. Crop rotation is the practice of planting a specific combination of crops in a specific sequence. This practice replenishes nutrients and helps manage pests. Crop rotation however requires greater management skills. Potential impacts from these CA practices guided selection of DCE attribute levels. Attribute levels were determined following results from

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[1] For additional information regarding CA practices, the authors suggest Lal (2001) and Hobbs et al. (2007).

on-farm CA field trials in the study area conducted by INIAP and a review of CA literature (see Table 1.3).

Attributes '*Four Year Yield*' and '*One Year Yield*' were chosen to measure farmers' valuation of expected intertemporal changes in productivity under CA compared to conventional practices and provide a measure of discounting. The attribute '*Four Year Yield*' reflected the expected yield after four years of CA. It took on three levels--*no change*, *15% increase,* and *30% increase.* '*One Year Yield*', the expected yield after one year, took two levels--*no change* and *10% decrease*. These levels reflect the realities of CA, where in the short run adopters face potential yield loss while soil health is improved; in the long run, productivity is expected to increase. Reduced tillage, a core CA practice, can cause short term yields to decline slightly due to weed growth, soil compaction, and soil temperature decreases, while increased soil quality can lead to long term gains (Vyn and Raimbault, 1993; Holmstrom et al. 1999; Hine and Pretty, 2008; Putte et al., 2010). For maize production, increased long-term yields from CA have been shown in Argentina (+34%) and Brazil (+67%) (Hine and Pretty, 2008). Cover crops have also been shown to increase long-term yields and crop quality, due in part to greater nutrient and water use efficiencies (Delgado et al., 2007). On-farm trials in both sub-watersheds have shown short-term yields of potatoes and maize to decrease by as much as 20% with long-term yields increasing by as much as 40%.

Attributes '*Planting Labor Days*' and '*Weeding Labor Days*' helped measure farmers' valuation of labor. Agricultural labor supply in both watersheds has decreased substantially in recent years along with a sharp increase in the price of wage labor, causing labor requirements to be a likely determinant of adoption. Both attributes took three levels with '*Planting Labor Days*' taking *no change*, *25% decrease* and *50% decrease*, while attribute '*Weeding Labor Days*' takes *no change*, *25% increase* and *50% increase*. In both sub-watersheds, the primary tillage practice of hand-hoe consumes the majority of planting labor costs. Under a CA system, where the reduced tillage practice of "jab-planting"[2] may be used, considerable planting labor savings may be realized. In other developing country contexts, this planting method has been shown to decrease planting labor by as much as 75% (IFAD, 2004). On-farm trials in both sub-watersheds have shown planting labor savings from implementing CA practices to range from 20% - 40%. Labor use for weeding will likely increase in the short run because hand-hoe tillage reduces populations of weed seeds. On-farm trials showed as much as a 45% increase in weeding labor associated with CA.

Soil erosion is a serious problem in both sub-watersheds and scarring from erosion is widely visible. By implementing CA practices such as cover crops, reduced tillage, and contour cropping, separately or in conjunction, erosion can be reduced. The attribute '*Soil Erosion*' took three levels--*low*, *medium* and *high*. By holding yields and costs fixed while varying levels of erosion, the erosion attribute reflects farmer preferences for off-farm and non-economic effects from erosion. Lessening erosion in these two sub-watersheds has potential implications for many Ecuadorians outside of this study area, as the larger Chimbo watershed these two sub-watersheds feed provides 30%-40% of the water to the most important river-system in western Ecuador (Alwang et al., 2009).

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[2] "Jab-planting" refers to the practice of using a pole (or stick) to manually "jab" a hole into the untilled ground and placing seed directly into the formed hole.

The final attribute included in the study was *'Cost'*. Four levels were used to describe '*Cost*'--*10% decrease*, *no change*, *10% increase* and *20% increase*; these reflect the expected change in cost of production associated with CA. Experimental trials showed changes in production costs ranging from a 45% decrease to a 65% increase in production costs depending on the combination of CA practices implemented. The average changes in production cost from the experiments ranged between a 15% decrease and 25% increase. It is important to note that growers were instructed to assume that all production attributes not mentioned in the DCE would remain identical to their current production status.

The initial strategy was to design a labeled DCE using individual CA practices for a given alternative and compare tradeoffs across both attributes and CA practices[3]. INIAP researchers had concerns about complexity and the cognitive burden placed on producers, so an unlabeled (generic) design was chosen. This design offers a hypothetical choice between two alternatives (a generic CA practice) and the status quo. With low education and literacy rates in the study area, attributes were shown to respondents using pictures and diagrams to facilitate understanding of the hypothetical tradeoffs (See Figure A.2). To decrease potential subjectivity bias brought about by this method producers were provided an explicit definition for each attribute and level (See Table 1.3).

Using prior information on expected parameter values, the DCE design was generated using a Bayesian efficient strategy. As previously noted, field trials were conducted investigating the profitability of CA based systems compared to conventional practices in both watersheds. Prior information on CA attributes was gathered using cost

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[3] A labeled design occurs when alternatives are assigned to represent a specific good or service; e.g., alternatives assigned to signify a particular CA practice. An unlabeled (generic) design occurs when the alternative is given no identifiable marking except for the attributes used to describe said alternative.

and revenue data from these INIAP research plots. *Cost's* prior was assumed fixed and negative. The prior value for *One Year Yield* was assigned a range from zero up to the negative of *Cost's* prior value multiplied by the revenue to cost ratio from field trial estimates for conventional farming practices. This process provides a willingness-to-pay (WTP) estimate that ranges from zero to a maximum where no additional increase in profit would occur. Assuming producers discount future yield benefits, the prior value of *Four Year Yield* was assigned a range nearly identical to *One Year Yield*, with the exception that the maximum value was discounted, to account for yield benefits being received in the future.

Prior values for *Planting Labor Days* and *Weeding Labor Days* were generated by multiplying the share of on-farm field trial production costs of each labor type with *Cost's* prior value. This provides a mean WTP estimate equal to the value currently experienced for individual labor costs. Both were assigned a range from twice their respective prior mean value to zero. As no data were available on the value placed on the off-farm impacts of erosion reduction, attribute priors for *Low Erosion* and *Medium Erosion* were assigned to generate a mean WTP equal to 10% and 5% of current costs, respectively. Similar to labor attributes, both were assigned a range from zero to twice their respective prior mean value.

To employ a Bayesian efficient strategy, mean values and distribution assignments of the attribute priors were needed. Without information on parameter distributions, all attribute priors except *Cost* were assigned a uniform distribution[4]. The design was generated using the software program NGENE and was optimized based on the D-efficiency of a multinomial logit model.

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[4] *Cost* is assumed fixed to ensure fully defined WTP estimates.

Employing this preliminary DCE design, pilot interviews were undertaken with a total of 17 responses. Applying conditional logit results from the pilot interviews, attribute priors were updated and another Bayesian efficient design was generated; again optimizing D-efficiency with priors set to follow a uniform distribution. A dominance restriction was also applied to ensure no dominant alternatives were presented to the participants.

The final DCE design consisted of 24 choice scenarios, with three alternatives in each scenario. Two alternatives described the hypothetical outcome after adopting a CA practice(s) and the third alternative reflected the status quo. To reduce respondent fatigue the 24 choice scenarios were randomly blocked into three choice sets, such that each respondent was asked to evaluate eight choice scenarios. Respondents were randomly assigned one of the three choice sets.

Before introducing the choice set, enumerators read aloud to the respondents an introductory script (see Figure 1.1) providing an explanation of the DCE, a description of each attribute, and its respective levels. A “Cheap Talk” script was included in the introduction to remind growers of their budget constraints. “Cheap Talk” has been shown to mitigate hypothetical bias when applied in developing country contexts (Chowdhury et al., 2011). To ensure respondents understood the questions, an example choice scenario was provided before beginning the choice scenario sequence (see Figure 1.2).

[Insert Figure 1.1 Here]

[Insert Figure 1.2 Here]

1.6 Econometric Techniques and Empirical Results

Many econometric techniques have been used for DCE estimation. The random parameter logit (RPL) model is a popular and flexible model widely used in the DCE literature. The RPL model allows for individual taste variation, unrestricted substitution patterns, and correlation in unobserved factors over choice scenarios (Train, 2009). Thus the utility of decision maker *i* from alternative *j* in choice situation *t* can be shown as:

$$U_{ijt} = \mu' x_{ijt} + \eta_i' x_{ijt} + \varepsilon_{ijt} \tag{3}$$

where x_{ijt} are observed attributes faced by individual *i* for alternative *j* in choice scenario *t* and ε_{ijt} is a random term with zero mean and IID over alternatives, with μ and η_i representing the attribute's population mean and random deviation among decision makers.

Because ε_{ijt} remains IID Type-I Extreme Value, the conditional probability is:

$$L_{ijt}(\beta_i) = \frac{\exp(\mu' x_{ijt} + \eta_i' x_{ijt})}{\sum_{k=1}^{K} \exp(\mu' x_{ikt} + \eta_i' x_{ikt})}. \tag{4}$$

The unconditional probability of the repeated choices is:

$$P_i(\theta) = \int S_i(\beta) f(\beta|\theta) d\beta, \tag{5}$$

with

$$S_i(\beta_i) = \prod_{t=1}^{T} L_{ij(i,t)t}(\beta_i). \tag{6}$$

Since the unconditional probability integral has no closed form solution, the likelihood function cannot be solved analytically and simulation methods must be used (Train, 2009; Hole, 2007):

$$\text{SLL}(\theta) = \sum_{n=1}^{N} \ln\left\{\frac{1}{R}\sum_{r=1}^{R} P_n(\beta^r)\right\}, \tag{7}$$

where β^r is draw *r* from density *f*. Five hundred Halton draws were taken as they have been shown to improve efficiency over pseudo-random draws (Train, 2009).

To ensure estimates consistent with economic theory, *Cost*, *Four Year Yield*, *Planting Labor*, *Low Erosion*, and *Medium Erosion* were assigned log-normal distributions[5]. *One Year Yield* and *Weeding Labor* were repeatedly found to have statistically insignificant standard deviations and were therefore assumed fixed.

The assignment of attribute distributions were supported through likelihood ratio tests, comparing fixed versus random attribute specifications. All attributes except *Erosion* are quantitative and were input at their given levels. The attribute *Erosion*, being qualitative, is "Effects" coded with *High Erosion* designated as the base value.

The *Alternative Specific Constant* (*ASC*), controlling for potential unobserved heterogeneity not accounted for by the independent variables, was assigned a normal distribution as growers could have mixed preferences about CA practices. The *ASC* was assigned to represent the difference in utility when selecting one of the two CA alternatives over the status quo option. Following a likelihood ratio test, all estimates were from the dataset pooled over both watersheds. Results indicate no significant presence of correlation among attribute parameters and therefore only main effect estimates are analyzed.

1.6.1 Random Parameter Logit Results

The RPL specification of Model 1 in Table 1.4 performed best. Employing a log-normal distribution ensures the proper theoretical sign for all individuals, but it can lead to abnormally high WTP estimates due to thick tails in the distribution. Thus the median WTP should be examined alongside the mean WTP. Sizable differences between the mean and median WTP values were found, suggesting the coefficient distributions were

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[5] The log-normal distribution of –1**Cost and* -1**Planting Labor* was taken to ensure the proper theoretical sign.

skewed upward (see Table A.1). An ex-post analysis reveals significant outliers of respondent specific attribute coefficients responsible for this skewness. Further examination uncovers multiple respondents exhibiting lexicographic preferences for attributes such as *Four Year Yield*, *Weeding Labor Days*, and *Planting Labor Days*[6].

To examine the impact of these outliers, Model 1 was re-run omitting respondents whose individual attribute coefficient was outside the 97.5 percentile for a given attribute. This was done across all six attributes and led to exclusion of approximately 15% of the respondents, for a final sample size of 198. The sizable difference previously seen between mean and median WTP values significantly diminishes (see Table 1.5).

Following removal of outliers, respondent and household characteristics (see Tables 1.1 & 1.2) were included through the use of interaction terms to address the first study objective. Including respondent characteristics as interaction terms helps account for heterogeneity and increases estimation efficiency. Seven respondent and household characteristics were found to significantly affect preferences for the two CA alternatives[7]: number of household adults older than 65 (-), education of farmer (+), off farm income (+), livestock ownership (-), level of risk aversion of farmer (-), viewing soil erosion as an individual farm issue (+), and wheat production (-) (Table 1.4).

[Insert Table 1.4 Here]

Results relative to adults older than 65 and education coincide with agricultural technology adoption literature; older farmers are less likely to adopt, while better-educated farmers are more likely (Feder and Umali, 1993). Off farm income increases the

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[6] However, it is possible that labor markets are imperfect and are therefore driving higher than anticipated WTP values.

[7] The sign of the variable's effect is in parentheses.

likelihood of choosing a CA alternative. Off farm income is accrued by members of that household and therefore may be associated with a binding labor constraint. Since households with off farm workers might need to save labor they may be more interested in CA, as CA labor requirements are lower than conventional farming methods. Livestock ownership is defined as the producer's Total Livestock Unit (TLU), which converts a range of different livestock types and sizes into one common unit; e.g., cow=0.7 units, pig=0.3 units, and chicken=0.2 units (Harvest Choice, 2011). The negative effect of livestock ownership is expected as the use of forage crops as groundcover in a CA system will compete with their use as animal feed. Also, as CA is focused solely on crop production, producers who rely primarily on livestock production for household income may view CA as an unnecessary risk to take for potential crop gains that comprise a smaller share of their overall household income.

Much uncertainty exists when adopting a new agricultural practice and attitude toward risk is likely to play a role in the decision-making process. Utilizing the risk assessment scenario from section four of the interview, risk aversion was found negative and highly significant, implying those producers who are more intolerant to risk are less likely to choose one of the two CA alternatives. Additional outreach and dissemination of the positive outcomes from on-farm trials of CA across both watersheds may lessen producer uncertainty surrounding these practices and increase the likelihood of risk averse producers adopting CA.

Soil erosion is viewed as a problem by 67% of the producers in the sample. Explaining to producers the purpose and potential benefits (e.g., decreased erosion and increased soil productivity) from CA, those believing soil erosion was an issue on their farm were significantly more likely to choose a CA alternative. This suggests that if producers are able to identify and understand how CA can impact their farming operations and outcomes, they may be more inclined to act. Dissemination of educational material outlining the consequences of soil erosion and CA's impact on erosion reduction might help spread CA practices in each watershed.

Wheat is only grown in the Illangama watershed and is produced by 16% of producers. Producers growing wheat were significantly less likely to choose the CA alternatives. The research did not include trials of CA for wheat, so wheat producers are obviously less likely to be enthusiastic about CA. Increased research on CA production impacts among alternative, less common crops, may facilitate more widespread adoption.

Inclusion of interaction terms in Model 1 leads to more consistently stable and significant estimates. The inclusion of interaction terms soaks up much of the heterogeneity and shifts the *ASC,* as expected, from significant to insignificant. Respondents were told that all other production attributes were held constant across choice alternatives. Therefore, respondents should only be biased between the DCE alternatives based on the attributes and levels given once the observed heterogeneity is accounted for by the interaction terms.

1.6.2 Willingness-to-Pay Estimation

The first two objectives of this paper were to identify the factors affecting the likelihood of adopting CA and determine their relative importance to producers. As model coefficients are not directly comparable, converting them into WTP estimates allows for a consistent comparison and the completion of the third and arguably most important objective: to estimate expected welfare changes associated with adoption.

Understanding welfare changes associated with CA adoption can help identify constraints to adoption and aid in extension and policy outreach development.

Because attribute levels were set as percentage changes from the status quo, WTP estimates should be viewed as relative cost changes. In assigning the *Cost* attribute to be log-normally distributed, issues of having a properly defined WTP estimate arise. Following Hess et al. (2010) and Carson et al. (2013), *Cost* was constrained to have a standard deviation equal to 0, thus ensuring a defined WTP.

Since CA attributes are modeled as either fixed or log-normally distributed, two WTP notations are used. Both the mean and median WTP value are inspected. Using the mean and standard deviation of the underlying normal distribution, if $b_k \sim N(\mu_k, \sigma_k^2)$, then $\beta_k \sim \exp\,(b_k)$, the mean and median WTP for two log-normally distributed coefficients can be computed as:

$$mean\ WTP_k = \frac{-\beta_k}{\beta_{Cost}} = \exp\,(\mu_k - \mu_{Cost} + \frac{1}{2}(\sigma_k^2 + \sigma_{Cost}^2), \mathit{with}\ \sigma_{Cost}^2 = 0\ ; \qquad (8)$$

$$median\ WTP_k = \exp(\mu_k - \mu_{Cost})\ . \qquad (9)$$

Computation of WTP for a fixed coefficient is more straightforward. Including the constraint, $\sigma_{Cost}^2 = 0$, the mean WTP can be shown as:

$$WTP_k = \frac{\beta_k}{\exp\,(\mu_{Cost})}\ . \qquad (10)$$

1.6.3 Willingness-to-Pay Results

Significant WTP values were found for all attributes with the exception of *One Year Yield* (Table 5*)*. Returns to farming tend to fluctuate from year to year, as producers face issues of erratic weather, pests, and disease. Insignificant WTP estimates for *One Year Yield* indicate that the possibility of a ten-percent decline in yield in the year following CA adoption was not associated with a decreased likelihood of selecting the CA alternative. With unstable yields being commonplace, the insignificance could be due to a willingness to tolerate a slight decrease in short run production to have stable and guaranteed higher future returns. In contrast, producers have a relative mean and median WTP value of 0.88% and 0.73%, respectively, for a 1% increase in *Four Year Yields*, meaning that they would be willing to pay 0.88% more in production costs to obtain a 1% increase in yield in year four and beyond. These results indicate a willingness to undertake long run investments. Extension efforts that emphasize expected future yield increases from CA adoption could have a significant impact on CA acceptance among resource-deficient producers.

[Insert Table 1.5 Here]

Planting Labor has a relative mean and median WTP value of 0.41% and 0.28%, respectively. Labor effort is most concentrated during planting when labor markets are tightest. As weeding operations account for a small share of total production cost and occur during periods of relative labor abundance, *Weeding Labor* was found to have a lower relative mean WTP value of 0.23%. The larger WTP value for *Planting Labor* implies that producers understand and value the skillset and time investment associated with particular planting practices compared to the more generic skillset required with that of *Weeding Labor*.

While respondents say they consider erosion to be an important consideration on their farm, they were unwilling to pay much to decrease it. Relative mean and median WTP values for *Low Erosion* and *Medium Erosion*, respectively, were 0.09% and 0.06%, and 0.06% and 0.04%. By allowing the erosion attribute to vary while holding all else constant, the low WTP values for erosion suggest farmers are unwilling to pay for off-farm and non-economic effects associated with erosion. Promoting CA practices by suggesting they will reduce off-farm impacts from erosion are unlikely to influence a producer's decision.

These results suggest that a different approach may be needed when promoting CA. Abatement in off-site impacts caused from the reduction of soil erosion has been a widely hailed social benefit of CA. It makes sense to explore policy mechanisms to compensate producers for these off-site benefits. One such policy mechanism is a "Payment for Environmental Services (PES)" scheme, where producers are compensated for adopting practices that reduce off-farm consequences of erosion. In Ecuador and other Latin American countries, PES policies have recently been used with moderate success (Francisco et al., 2013). While this type of policy faces institutional complexities, the previous PES policy results do provide some promise.

Using production cost and revenue data from research plots in both watersheds spanning a 3-year period (SANREM, 2013), it was possible to determine if the production costs/revenue associated with current farming methods fall within the boundaries of the WTP results. Dependent on the crop, under current farming methods planting labor accounts for approximately 30% - 50% of production costs, weeding labor accounts for 10% - 30%, and the return on investment (i.e.; profit) ranges between 80% and 300%. No data exist on economic impacts of erosion rates in either watershed. Comparing these figures with the WTP estimates seen in Table 1.5, exclusion of the outliers produces WTP estimates that fall within the cost and revenue structure of current practices, providing a realistic estimation of the value that producers place on the various CA/farming attributes.

1.7 Conclusion

Uncertainty exists about the spread of CA among smallholding farmers in developing countries. In areas with degraded soils and falling productivity, CA has promise. The aim of this paper was to add to the limited literature on how poor producers view production attributes associated with CA and to provide insights into the potential for CA in marginal, steeply sloped, small-scale production systems. Conservation agriculture is a possible solution to environmental problems associated with small-scale farming on marginal lands, yet, because little is known about attitudes toward CA attributes, research and extension agencies have been unsure about how to tailor their messages to the target audience.

Nearly 25% of the study's household population was interviewed, providing a representative sample of households in both watersheds. The study identified the key attributes related to farming in the area, conducted a DCE to determine the relative importance of CA attributes, and measured expected welfare changes associated with CA adoption. Three attributes were found to be of significance to producers: crop yields, farm labor, and cost of production. For successful adoption of CA practices to occur, it is critical that the CA practices being promoted target the constraints associated with the three attributes mentioned above. This may require outreach specialists (e.g., INIAP research scientists) in the study area to reconsider the set of CA practices currently being promoted and ensure the supported practices target these constraints.

The DCE results showed producers were overwhelmingly concerned with changes to cost of production, followed by long-term yield increases, and planting and weeding labor demands. Particularly in developing countries, where farmers tend to be poor, cost may be seen as one of the largest drivers of decisions. Poor producers in marginal areas face cash flow challenges and labor shortages. Outreach messages highlighting CA cost savings should help CA spread. As labor costs increase throughout much of the Andes labor savings technologies are becoming more relevant. Savings of other out of pocket input costs, such as seed, fertilizer, and herbicides are also important.

Producers were generally found willing to consider the long-term consequences of implementing new production practices. Farmers are willing to pay moderate short-term costs for additional future benefits. For example, while producers are indifferent to a moderate decrease in one-year yield, they are willing to pay an average of 0.88% in additional cost for a yield increase of 1% four years after adoption. The authors caution against assuming the relationship between WTP and future yields is strictly linear and without limits, as income and credit constraints will likely restrict the amount producers may "invest" to reach these long-term yield gains.

While over two-thirds of respondents acknowledged that soil erosion was a problem on their farm, their valuation of erosion reduction was near zero. Farmers value on-farm gains and place less emphasis on damages affecting others. This may be attributed to a lack of awareness of the impact of agricultural production on downstream populations. A disconnect in awareness between on-farm activities and downstream effects is understandable. Travel and communication is limited in Ecuador's highland regions and so such impacts may never enter into the producer's decision-making process. Outreach raising awareness of off-farm impacts of erosion can raise understanding of the downstream consequences of their actions, which may also increase the likelihood of adopting CA.

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Tables

Table 1.1. Mean Values of Socio-Demographic Variables

Variable	Description	Total	Alumbre	Illangama
Age	Average age of respondent	44.4	46.7	40.2
Male	1 if Male respondent	0.42	0.39	0.49
Education[a]	Average education level of respondent	3.7	3.8	3.5
Household Head	1 if respondent is head of household	0.61	0.59	0.65
Agricultural Organization	1 if household belongs to an agricultural organization	0.48	0.29	0.82
Extension Agent	1 if household has collaborated with an agricultural extension agent	0.29	0.21	0.42
Household Size	Number of individuals living in the household	5.1	4.6	5.9
Household Males	Number of males living in the household	2.4	2.2	2.9
Children under 18	Number of children under the age of 18 living in the household	2.4	2.1	3.0
Adults over 65	Number of adults over the age of 65 living in the household	0.4	0.5	0.2
Hectares	Number of hectares the household farms	3.9	4.1	3.6
# Lots	Number of lots the household farms	1.8	1.5	2.4
Soil Erosion	1 if household views soil erosion as a problem on their farm	0.67	0.61	0.80
CA Knowledge[b]	1 if respondent has knowledge of CA practice(s)	2.9	2.7	3.4
Off Farm Income	1 if household collects income from off-farm employment	0.36	0.31	0.46
Remittances	1 if household receives remittances from non-household family members	0.20	0.19	0.22
Loans	1 if household has taken agricultural loans	0.30	0.16	0.55
Risk Aversion[c]	Respondent's average relative risk aversion	3.69	4.50	2.22
N	Number of respondents	233	150	83

Note: N.A. = Not Applicable

[a] None=1, Knows the Alphabet=2, Elementary School=3, Junior High School=4,High School=5, College=6.

[b] Four CA practices were included: Contour Cropping, Reduced Tillage, Cover Crop, and Crop Rotation.

[c] Following Hanna et al. (2001).

Table 1.2. Mean Values of Agricultural Crop & Livestock Variables

Variable	Description	Total	Alumbre	Illangama
Potatoes	1 if household produces potatoes	0.37	0.04	0.98
Maize	1 if household produces maize	0.64	0.99	0.02
Quinoa	1 if household produces quinoa	0.14	0.00	0.39
Barley	1 if household produces barley	0.27	0.04	0.69
Wheat	1 if household produces wheat	0.06	0.00	0.16
Melloco	1 if household produces melloco	0.31	0.00	0.87
Beans	1 if household produces beans	0.93	0.91	0.96
Peas	1 if household produces peas	0.39	0.59	0.05
Fruit	1 if household produces fruit	0.10	0.15	0.00
Other	1 if household produces other crops	0.42	0.27	0.70
Livestock Ownership	Tropical Livestock Unit index	4.02	3.16	5.56

Note: Standard deviation in parenthesis ( )

Table 1.3. DCE Attributes and Levels

Attribute	Description	Levels
One Year Yield	The change in yield one year after adopting CA practice(s)	-10% No Change*
Four Year Yield	The change in yield four years after adopting CA practice(s)	No Change* +15% +30%
Planting Labor	The change in planting labor after adoption of CA practice(s)	-50% -25% No Change*
Weeding Labor	The change in weeding labor after adoption of CA practice(s)	No Change* +25% +50%
Erosion	The impact of soil erosion after adoption of CA practice(s)	Low Medium High*
Cost	The change in production costs after adoption of CA practice(s)	-10% No Change* +10% +20%

Note: * denotes the status quo (base)

Table 1.4. Model 1 Main Effects and Main Effect with Interactions Estimates

	Main Effects[a]			Main Effects with Interactions[a]		
DCE Attribute	**Natural Log Mean**	**S.D.[b]**	**Mean**	**Natural Log Mean**	**S.D.[b]**	**Mean**
ASC	-	1.159***	0.944***	-	0.896***	0.358
One Year Yield	-	-	0.124	-	-	0.135
Four Year Yield	-0.227	0.705	1.021**	-0.175	0.620	1.017**
Planting Labor	-1.222*	0.936**	-0.457***	-1.129	0.860	-0.468***
Weeding Labor	-	-	-0.274	-	-	-0.269
Low Erosion	-2.872***	1.156***	0.110**	-2.738***	0.971***	0.104**
Medium Erosion	-3.108***	0.925	0.069	-3.070***	0.975**	0.075*
Cost	0.142	0.00	-1.153***	0.140	0.00	-1.150***
Interactions						
Adults >65					-0.262*	
Education					0.135*	
Off Farm Income					0.460**	
Livestock Ownership					-0.060**	
Wheat					-1.179***	
Risk Aversion					-0.096***	
Soil Erosion					0.582***	
Log-likelihood		-1,562.38			-1,537.74	
AIC		3,150.75			3,129.48	
BIC		3,234.84			3,304.12	
Sample size		4,761			4,761	

Note: *** 1% significance, ** 5% significance, * 10% significance

[a] Random Parameter Logit: One Year Yield and Weeding Labor are fixed; ASC is Normally distributed; All other attribute parameters (including Cost) are Log-normally distributed; Constraint: Standard Deviation of Cost = 0

[b] Standard Deviation

Table 1.5. Willingness-to-Pay Estimates

		Main Effects		Confidence Interval[a]	
Attribute	Improvement	Mean WTP	Median WTP	Delta Method	Fieller Method
One Year Yield	A 1% increase in One Year Yields	0.11	0.11	-1.43 ~ 1.65	-2.04 ~ 1.70
Four Year Yield	A 1% increase in Four Year Yields	0.89**	0.69	-0.07 ~ 1.84	0.11 ~ 2.59
Planting Labor	A 1% reduction in Planting Labor	0.40**	0.26	-0.02 ~ 0.81	0.10 ~ 1.24
Weeding Labor	A 1% reduction in Weeding Labor	0.24*	0.24	0.00 ~ 0.47	-0.05 ~ 0.52
Low Erosion	From High Erosion to Low Erosion	0.10**	0.05	-0.01 ~ 0.20	0.02 ~ 0.30
Medium Erosion	From High Erosion to Medium Erosion	0.06*	0.04	-0.02 ~ 0.14	0.00 ~ 0.20
		Main Effects with Interactions			
One Year Yield	A 1% increase in One Year Yields	0.12	0.12	-1.43 ~ 1.67	-2.03 ~ 1.73
Four Year Yield	A 1% increase in Four Year Yields	0.88**	0.73	-0.09 ~ 1.86	0.10 ~ 2.63
Planting Labor	A 1% reduction in Planting Labor	0.41**	0.28	-0.02 ~ 0.83	0.10 ~ 1.27
Weeding Labor	A 1% reduction in Weeding Labor	0.23*	0.23	0.00 ~ 0.47	-0.05 ~ 0.52
Low Erosion	From High Erosion to Low Erosion	0.09**	0.06	-0.01 ~ 0.19	0.01 ~ 0.29
Medium Erosion	From High Erosion to Medium Erosion	0.06*	0.04	-0.02 ~ 0.15	0.00 ~ 0.21

Note: *** 1% significance, ** 5% significance, * 10% significance

[a] Confidence Intervals using both the Delta and Fieller method are taken at 90%

Figures

Figure 1.1. Discrete Choice Experiment Introduction Script

N.B.: Writing below in italics and enclosed by parenthesis ( ) is not read to respondents but rather a cue for the enumerator to follow during the DCE introduction process.

This section involves a set of farming methods known as "Conservation Agriculture." The main objective of these methods is to increase soil fertility and decrease soil erosion. We have identified six farm production factors that may potentially change after adopting these types of practices and we would like to know your preferences towards them. The six production factors are: ***Change in yield one year after adoption, Change in yield four years after adoption, Change in number of days spent on labor for planting, Change in number of days spent on labor for weeding, Change in soil erosion, and Change in cost of production***.

In a moment I will ask you to choose between three different farming scenarios. Two of these scenarios will describe a hypothetical outcome were you to adopt a conservation agriculture practice. The third scenario will be if you were to continue with the farming practice(s) that you currently use. The three farming scenarios are described by the six farm production factors that I previously mentioned. These farm production factors can take different values, which I will describe now.

(*After this script is read aloud by the enumerator, respondents are shown a print of the six DCE attributes and their respective levels as seen in Figure A.2. The enumerator describes the six attributes and their respective levels using the attribute description shown in Table 1.3. After this has been completed, the enumerator continues with the introductory script below.)*

When making your choice between the three different farm scenarios please assume all production factors, other than the six just discussed, regarding your farm operation will be no different across the three farming scenarios.

When you make your choice, please do so under the assumption that given the alternative you choose, the levels of the farm production factors shown would come true. It is very important to remember your farm income and budgetary constraints your family faces when making your choice. Before we begin, we will go through an example together.

(*The enumerator shows the respondent a choice scenario example as seen in Figure 1.2 and reiterates the previous points from the DCE introduction. Once the respondent and enumerator complete the choice scenario example, the eight choice scenarios are presented.*)

Appendix A

Table A.1. Willingness-to-Pay Estimates (All Respondents)

		Main Effects		Confidence Interval[a]	
Attribute	**Improvement**	**Mean WTP**	**Median WTP**	**Delta Method**	**Fieller Method**
One Year Yield	A 1% increase in One Year Yields	-0.50	-0.50	-2.48 ~ 1.49	-4.31 ~ 1.34
Four Year Yield	A 1% increase in Four Year Yields	1.77**	0.50	0.26 ~ 3.28	0.71 ~ 5.61
Planting Labor	A 1% reduction in Planting Labor	0.97*	0.12	0.10 ~ 1.93	0.26 ~ 3.29
Weeding Labor	A 1% reduction in Weeding Labor	0.40**	0.40	0.09 ~ 0.70	0.09 ~ 0.94
Low Erosion	From High Erosion to Low Erosion	0.27*	0.03	0.00 ~ 0.55	0.04 ~ 0.88
Medium Erosion	From High Erosion to Medium Erosion	0.12*	0.03	0.00 ~ 0.25	0.03 ~ 0.42
		Main Effects with Interactions			
One Year Yield	A 1% increase in One Year Yields	-0.55	-0.55	-2.51 ~ 1.40	-4.28 ~ 1.24
Four Year Yield	A 1% increase in Four Year Yields	1.77**	0.43	0.28 ~ 3.26	0.71 ~ 5.43
Planting Labor	A 1% reduction in Planting Labor	1.03*	0.11	0.00 ~ 2.07	0.22 ~ 3.34
Weeding Labor	A 1% reduction in Weeding Labor	0.40**	0.40	0.09 ~ 0.70	0.09 ~ 0.92
Low Erosion	From High Erosion to Low Erosion	0.27*	0.03	0.00 ~ 0.55	0.04 ~ 0.87
Medium Erosion	From High Erosion to Medium Erosion	0.11*	0.03	0.00 ~ 0.22	0.02 ~ 0.38

Note: *** 1% significance, ** 5% significance, * 10% significance

[a] Confidence Intervals using both the Delta and Fieller method are taken at 90%

Figure A.1. Risk Assessment Experiment

1. Suppose that your farm is the only income your family earns and the income you earn currently from your farm can be guaranteed for life. You are given the opportunity to implement at no additional costs the 4 CA practices previously mentioned: Cover Crop, Crop Rotation, Reduced Tillage and Contour Cropping, with a 50-50 chance it will double your income after 4 years and a 50-50 chance that it will cut your income after 4 years BY 20%. After 4 years, the change will be permanent.

Would you adopt the practices? YES/NO
If your answer to #1 is NO, go to question #2.
If your answer to #1 is YES, go to question #5.

2. Suppose the chances were that there was a 50-50 chance it will double your income made over 4 years and a 50-50 chance that it will cut your income made over 4 years BY 10%.

Would you adopt the practices? YES/NO
If your answer to #2 is NO, go to question # 3.
If your answer to #2 is YES, your risk tolerance is MODERATE.

3. Suppose the chances were that there was a 50-50 chance it will double your income made over 4 years and a 50-50 chance that it will cut your income made over 4 years BY 8%.

Would you adopt the practices? YES/NO
If your answer to #3 is NO, go to question #4.
If your answer to #3 is YES, your risk tolerance is LOW

4. Suppose the chances were that there was a 50-50 chance it will double your income made over 4 years and a 50-50 chance that it will cut your income made over 4 years BY 5%.

Would you adopt the practices? YES/NO
If your answer to # 4 is NO, your risk tolerance is EXTREMELY LOW.
If your answer to #4 is YES, your risk tolerance is VERY LOW.

5. Suppose the chances were that there was a 50-50 chance it will double your income made over 4 years and a 50-50 chance that it will cut your income made over 4 years 33%.

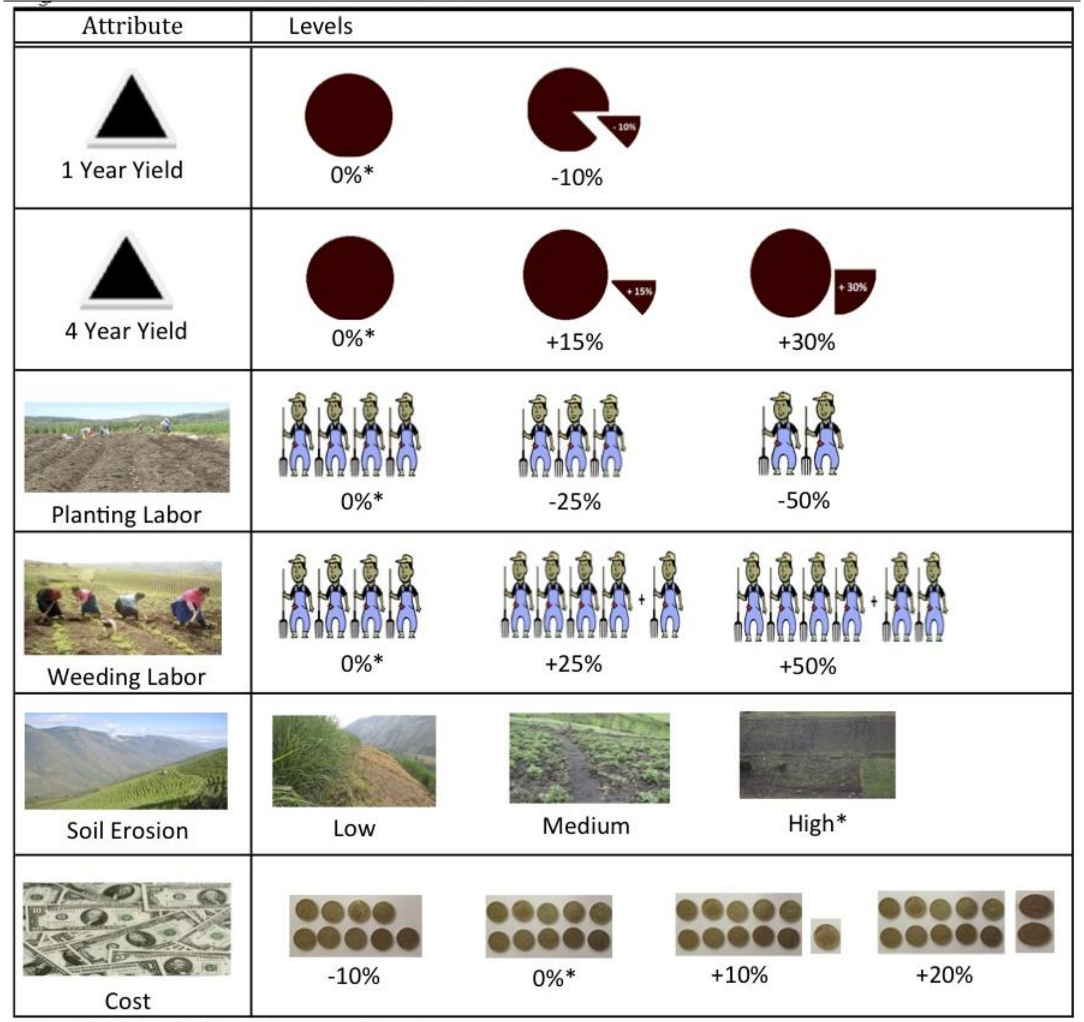
Would you adopt the practices? YES/NO
If your answer to #5 is NO, your risk tolerance is MODERATELY HIGH.
If your answer to #5 is YES, go to question 6.

6. Suppose the chances were that there was a 50-50 chance it will double your income made over 4 years and a 50-50 chance that it will cut your income made over 4 years BY 50%.

Would you adopt the practices? YES/NO
If your answer to #6 is NO, your risk tolerance is VERY HIGH.
If your answer to #6 is YES, your risk tolerance is EXTREMELY HIGH.

Note: Risk Tolerance descriptions taken from Hanna et al. (2001)

Figure A.2. Discrete Choice Experiment Attributes and Level



Attribute	Levels			
1 Year Yield	0%*	-10%		
4 Year Yield	0%*	+15%	+30%	
Planting Labor	0%*	-25%	-50%	
Weeding Labor	0%*	+25%	+50%	
Soil Erosion	Low	Medium	High*	
Cost	-10%	0%*	+10%	+20%

Note: * indicates the base (status quo) level

2 An Evaluation of Firm and Contract Characteristics Valued by Supply Chain Partners in Specialty Crop Marketing Channels

2.1 Introduction

Specialty crops (SC) are an integral portion of the U.S. food landscape. In 2012, SC production reached nearly $43 billion in sales value, and accounted for 11% of all U.S. agricultural sales (Johnson, 2014a); these values reflect an increase of 30% over the last five years (Johnson, 2014a). This production was generated by 244,974 farms (10% of all U.S. total), and provided employment to more than 1.5 million workers (USDA NASS, 2012).

An increasing number of legislative acts and provisions designed to support and provide oversight serve as further testament to the importance of this sector. Aiming to increase the efficiency and competitiveness of SC production, the *Specialty Crop Competitiveness Act of 2004* was enacted and further reinforced in the *Food, Conservation, and Energy Act of 2008* (i.e., the *2008 Farm Bill)*. In the *Agricultural Act of 2014* (i.e., the *2014 Farm Bill)*, SC production was allocated an average of $739 million in mandatory annual spending from 2014 – 2018, a 10% increase over the 2008 Farm Bill, along with an additional $257 million in discretionary annual spending (Johnson, 2014b). Other legislative measures, including programs such as the Market Access Program (MAP), the Foreign Market Development Program (FMDP), and the Technical Assistance for Specialty Crops Program (TASC) has either directly or indirectly encouraged consumption of these products.

Marketing methods play a vital role in the efficiency of any supply-chain, especially for perishable goods. While the marketing structure of livestock and grain markets in the U.S. has been extensively studied, the price setting process, buyer-seller relationships, and factors influencing the type, duration, and timing of business relationships in the markets for specialty crops[8] (SC) are less well understood. This is particularly true in the case of buyer relationships with small-scale[9] SC farms.

Small-scale farms frequently opt to market through direct-to-consumer marketing channels such as farmers' markets, roadside stands, and pick-your-own operations. There is, however, growing interest among, and increasing consumer demand for, small-scale SC producers to participate in traditional fruit and vegetable marketing channels. Sales to wholesalers or distributors, for example, could offer small farms reduced per-unit transaction costs and help reduce price, sales completion, and other forms of risk. From a buyer perspective, increased purchases of SC through contracts is a potential means of securing a supply of SC from in-demand small farmers, and improving price stability over that in unpredictable SC spot markets.

The perishability of most SC requires an expeditious transfer between producers and buyers. The opportunities and challenges of marketing specialty crops, however, vary by crop, final use, marketing channel, and regulations in the localities of the buyer and/or the seller. Producers selling for later processing may face different barriers than those selling to fresh markets; e.g., market access, quantity demands, lower price, and also state and local governance restrictions. The seasonal nature of SC production and, in some

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[8] The USDA defines specialty crops as fruits, vegetables, tree nuts, dried fruits, and horticulture and nursery crops (Johnson, 2014a). For the remainder of this paper, the specialty crops considered will be only fruits and vegetables used for human consumption.

[9] The USDA defines "small-scale" farms as those with less than $350,000 in gross annual sales (Hoppe and MacDonald, 2013).

instances, demand, further challenges this marketing system. The growth in demand for "locally grown" or produced foods, by customers of mainstream food retailers and foodservices, adds to the challenges of these supplier networks.

Limited information is available on specific factors that affect the use of contracts by small-scale SC producers. Contracts can differ greatly in their terms and conditions (or attributes), such as volume and quality requirements, price, payment mechanisms, delivery requirements, penalty clauses, contract length, requirements to use particular inputs or production practices, and technical assistance provided by the buyer. Buyer characteristics can also play a role in the willingness of a producer to enter into a contract. For small-scale producers who often use direct-to-consumer marketing channels, buyer characteristics such as their location, length of time in business, size, workplace values, and characteristics of the firm's ownership (local/non-locally owned, family-owned business, etc.) may affect their willingness to enter into a contractual agreement.

A better understanding of the dynamic relationship between SC producers and buyers is essential in exploring the potential for more efficient marketing outcomes for producers. Clearly identifying objective characteristics valued in producer-buyer contractual relationships will assist firms in more accurately targeting their sales or procurement efforts. With a goal to contribute to improved efficiency and profitability of small-scale SC farms, and consumer access to small-farm SC products, this study investigates the relative importance of contract attributes and buyer business characteristics on the willingness of small-scale SC farms to enter into contractual agreements. Specifically, using a Choice Experiment (CE) approach, this study: (1)

identifies key contract characteristics and buyer attributes valued by small-scale producers; (2) quantifies tradeoffs small-scale specialty crop producers are willing to make between buyer attributes and contract characteristics when establishing a new contractual relationship; and (3) identifies and assesses the factors influencing these tradeoffs. This research fills a void in the literature regarding which specific factors facilitate and deter small-scale specialty crop producers from entering into contractual marketing relationships.

This issue is examined from the perspective of small-scale SC producers in the U.S. states of Virginia (VA) and North Carolina (NC). These states are neighbors and share many similarities in their agriculture production environment, types of agricultural output, and use of particular production and marketing practices. From 2007 thru 2012, the number of SC farms in NC and VA rose nearly 10% (12,751 farms), with a similar increase in the amount of acreage planted (300,411 acres) (USDA NASS, 2012). During this same period, the market value of SC products sold by farms in these states rose by approximately 10% to $1.6 billion (NC: $1.17 billion; VA: $0.42 billion), with an average return of $5,300 per harvested acre (NC: $5,100/acre; VA: $5,800/acre) (USDA NASS, 2012). Currently, contract use between small-scale SC producers and food buyers in each state is very limited.[10] This circumstance is similar to that found in many other states with diversified, and relatively small-scale SC production.

This study proceeds by briefly reviewing findings from previous literature regarding agricultural contract use. The conceptual framework is then described followed

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[10] This information was garnered through discussions with small-scale SC producers, Cooperative Extension personnel, and industry experts from each state. Verbal/handshake contracts/agreements are observed between small-scale producers and food retailers and restaurants, and "contract" style agreements exist in the form of Community Supported Agriculture (CSAs) programs.

by the methods used and data collected. Results are detailed along with a discussion of the findings and resulting conclusions.

2.2 Review of the Literature

Contracts can offer benefits to both buyers and sellers. Buyers, for example, can require certain traits be present in the product under contract, as well as help to ensure their firm has a steady supply of product (Rehber, 1998; Du et al., 2013). For sellers, risk can be reduced and shared with buyers and allow for the growing of nontraditional crops that would otherwise go unproduced (Du et al., 2013). In addition, in examining U.S. grain markets, Hu (2012) provides evidence that contract farming can provide a positive and significant effect on average returns compared to cash/spot market sales. Similarly, Park et al. (2014) find that producers who diversify their marketing approaches, through channels such as direct to consumer outlets as well as intermediated sales to retail outlets, have higher sales compared to producers who use fewer marketing alternatives. Other seller benefits reportedly to be gained through contracts are access to credit and additional markets (e.g., retail food buyers, brokers, and distributors, as well as schools, hospitals, and prisons), greater income stability, and quality price premiums, among others (MacDonald, 2015; Du et al., 2013; Hu, 2012; MacDonald and Korb, 2011; Hudson and Lusk, 2004; and Wu, 2001). Contracts may, however, reduce the seller's decision-making capabilities (i.e., autonomy) and cause buyers to possibly face a moral hazard from sellers due to asymmetric information (Hudson and Lusk, 2004; and Hueth and Ligon, 1999).

In the U.S., SC are frequently marketed through contracts. In 2013, 50% of U.S. fruit, nut, and berry production was marketed through contracts, along with 29% of vegetable and melon production (MacDonald, 2015). This equated to nearly $19 billion in contracted production (USDA NASS, 2016; USDA ERS, 2015). At present, contract use is skewed by farm size with the bulk of fruits and vegetables produced under contract being sourced from large-farm operations (MacDonald and Korb, 2011; MacDonald et al., 2013). Fruit producers who use contracts produce nearly three times more in production value than those not using contracts; this gap is even greater in vegetable production where the value of production of contract users exceeds that by non-contract users by approximately eight fold (MacDonald et al., 2013). Large-scale farms engaging in contracts may benefit from efficiency gains, such as decreased marketing costs, or improved inputs through technology transfers, that are not available to the often smaller-scale farms that don't use contracts (MacDonald et al., 2013). These potential benefits may further widen the competitive gap between farms of different scales of production.

Due to their high volume demands, it is common practice for SC buyers to contract primarily with large-scale producers, overlooking small-scale producers who are often perceived as unable to meet quantity requirements (Clark et al., 2011). Increased risk and transaction costs associated with aggregating products from numerous small-scale producers are additional causes for bypassing these producer types. Simultaneously, small-scale producers face their own obstacles to contract use. Examining US Southeastern small-scale SC producers, Westray (2012) and Nunnelly (2012) found that standard contractual clauses and arrangements significantly limit the interest and ability of these producers to engage in contract use when marketing to institutional food buyers. Producers cited prices received, delays in payment, quantity demands, and product attribute requirements as major concerns. Additional contract concerns included delivery challenges and food safety and insurance requirements.

Recent research has begun examining producers' contract enrollment decisions using stated preference approaches (Peterson et al., 2015; Vassalos et al., 2013; Schipmann and Qaim, 2011; Blandon et al., 2009; and Hudson and Lusk, 2004). Stated preferences allow attitudes towards a particular good/service and its attributes to be measured without the respondent having to have consumed/used the good/service in question. This is accomplished by asking the respondent hypothetical questions regarding scenarios of interest. Choice experiments, which are used in this study, are one of several forms of stated preference valuation methods.

Vassalos et al. (2013) evaluate contract choice by wholesale tomato producers by four characteristics: price, volume requirement, penalty (a % reduction in price for failing to satisfy contractual terms regarding volume and quality standards), and certification cost (used as a quality standard mechanism). As economic theory suggests, these authors find that the cost of certification as well as the potential for a penalty significantly reduces the utility associated with accepting an agricultural contract. While producers reported that satisfying volume requirements was a major deterrent to accepting a contract, results indicated no significant effect on contract enrollment rates.

Examining contract preferences of sweet pepper producers, Schipmann and Qaim (2011) considered four contract attributes: price, mode of payment, buyer provision of production inputs and/or credit, and the producer's relation to buyer. Results show that producers prefer knowing the buyer personally before entering a contract, and the provision of inputs and credit is favored. Previous experience with contracts and engaging in off-farm employment was revealed to make the producer more contract-averse. The negative effect of off-farm employment was thought to be due to the relatively higher opportunity cost for those involved in contracting for part-time versus full-time farmers.

Surveying farmers ranging from fruit and vegetable growers to livestock producers, Hudson and Lusk (2004) find that contract length (number of years), asset specificity (percentage of total assets that can be used only for production of the good under contract), and loss of autonomy significantly decrease the acceptance of a contract. Unsurprisingly, preferences for firm and contract characteristics across these studies were shown to exhibit significant heterogeneity among producers.

It is important to note also that, while agricultural contracts are often thought of as being constructed solely on the relationship between a producer, a buyer, and characteristics of the product and market in question, consumers of a final good can influence attributes of the contract. This may be particularly the case of unprocessed perishable products like fresh fruits and vegetables. Research by Wu (2001) shows how heterogeneity of consumer preferences can lead to heterogeneity in contract structure between producers and buyers. Variation in consumer preferences for foods grown using certain practices (e.g., organic vs. non-organic), on different farm types (e.g., family farm vs. corporation), or in specific areas (e.g., local vs. non-local) can generate a higher willingness-to-pay (WTP) for foods with a given set of characteristics. For example, studies looking at consumers' preferences for fruits and vegetables in U.S. Southeastern states have shown consumers are willing to pay a price premium for foods labeled "Local" and/or "Organic" (Maples et al., 2014; Carrol et al., 2013; Young, 2012). SC buyers are likely to account for such heterogeneity and potential increased sales price by designing contracts based on these preferences, the individual producer, and the product in question.

2.3 Conceptual Framework

In practice producers express marketing preferences through their decisions concerning whom they sell their products to. As such, to understand the relative importance of producer preferences for buyer and contract characteristics, this study assumes a producer's choice to enter (or not enter) into a contract is governed by a random utility framework (McFadden, 1974). This framework assumes that a producer will choose to market their produce through a given contractual agreement if the utility received is greater than doing otherwise.

In addition, following Lancaster's (1966) consumer theory approach, the utility received from marketing through a contract can be partitioned into the utility derived from the attributes that make up the contract. Given the choice between a set of marketing methods (for example, contract with a wholesaler vs. direct-to-consumer sales) with various attributes and requirements, a producer will choose the method that maximizes his/her utility. Combining these economic theories, a producer's indirect utility function can be expressed as:

$$U_{ni} = V_{ni} + \varepsilon_{ni}, \quad (1)$$

where utility for producer *n* and marketing method *i* can be divided into a deterministic portion V_{ni}, which is observed by the researcher, and a stochastic portion ε_{ni}, which is unobserved and known only to the producer. Designating utility to be linear in parameters, $V_{ni} = \boldsymbol{\beta}'\mathbf{X}_{ni}$ where $\mathbf{X}_{ni}$ is a combination of marketing method attributes and producer specific characteristics, and $\boldsymbol{\beta}$ is a vector of unknown parameters to be estimated. Due to this uncertainty, the analysis of producers' choice among marketing options becomes a probabilistic choice (Bateman et al., 2002):

$$Pr_{ni} = Pr\left(U_{ni} \geq U_{nj}\right) \forall\, i \& j \in C \text{ and } i \neq j, \tag{2}$$

where marketing methods *i* and *j* belong to choice set *C,* and Pr_{ni} is the probability of producer *n* selecting method *i* from the choice set *C*.

2.4 Methods and Data

2.4.1 Data Collection

Data used in this study was collected using initial qualitative (Phase I) and subsequent quantitative (Phase II) research techniques in the form of a choice experiment administered through a survey. As an initial step, information regarding producers' experiences with contracts, along with perceived issues and informational needs when selecting and establishing new business partnerships through contracts was collected. This information was gathered through a short series of open-ended questions, which were administered through in-depth personal interviews. To help ensure input from a wide variety of producers was gathered, a careful approach was used to identify and recruit these participants. An inventory of VA farmers' markets was developed. From this, five regions and nine markets in these areas were randomly selected for interviews. At each of these sites an inventory of producers present on that market day was taken (through a walk through of the market), and producers were randomly selected from this list. Selected producers were approached and asked if they would be willing to participate in this study. In total, 28 in depth interviews with producers were completed across nine sites.

Results from Phase I interviews, discussions with Cooperative Extension personnel, industry experts, and a review of agricultural contract literature were used as inputs into a survey, which was developed and administered in Phase II of the data collection. This survey was comprised of three sections. Using a variety of question formats, the first section explored producers' use of contracts, preferences towards contract characteristics, and potential benefits and outcomes of contract adoption. The second section had producers participate in a contract enrollment CE where they were asked to choose between alternative contracts that varied across characteristics of the contract and the buyer. Since this study seeks to assess producer willingness to adopt a tool that is not used by all producers, a CE was selected as the appropriate method. Additional details of this experimental design are provided below. The final section collected characteristics of the producer and farm operation.

The survey was pre-tested with farmers attending three farmer education conferences located throughout the geographic region of focus. Using feedback gained through each event, the survey was iteratively refined to improve the survey design, question format, and to clarify question wording.

The survey was administered using both paper and online formats, between January-May 2015. While ideally this survey would have been sent directly to all small, specialty crop producers in the geographic area of focus, a list of individuals in this population and their contact information is not available. As such, extensive efforts were made to distribute the survey to as broad and comprehensive group as possible. Hard copies of surveys were distributed and collected by members of the research team at a variety of meetings and events attended by small specialty crop farmers such as

Cooperative Extension events, on-farm consultations, producer organization meetings, food system organization seminars, and other producer orientated events in both states[11]. The online version of the survey was administered using Qualtrics. Invitations to participate in the surveys were emailed to members of major organizations and list serves for which small, specialty crop farmers are subscribers including state farmer's organizations, Cooperative Extension and Farm Bureau list serves, membership lists of regional and state food system organizations, farmers' market members, and others. As an incentive to help increase participation rates, farmers had the option of be entered in a raffle to win one of five $150 pre-paid Visa gift cards.

In total 384 surveys were received; of these 55.4% were paper and 44.6% were online submissions[12]. A total of 797 in-person paper surveys were distributed with 213 being returned for a response rate of 26.7%. The population count for those receiving the online survey is unknown. However, 171 producers began the survey and 97 fully completed it for an online completion rate of 56.7%.

2.4.2 Choice Experiment Design and Estimation

Developed to determine the value of product attributes in marketing and transportation, choice experiments (CEs) are now applied in many fields (Louviere et al., 2000). In this study, the CE asked SC producers to choose between two options of different contractual agreements (alternatives), or the status quo (neither contract alternative). Including a status quo option allows for the estimation of welfare measures that are consistent with demand theory (Bateman et al., 2002). Since producers are not required to select either

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[11] Due to privacy concerns, worries by producer association personnel about inundating their list serves with multiple survey notifications, and a reliance on the voluntary cooperation of producer associations, a single email was sent to each producer association's list serve.

[12] The results of this study were not statistically different across the two survey methods.

alternative, they are not forced to select an alternative that they otherwise would not desire.

The contract options varied with respect to both contract features and buyer characteristics.[13] When choosing attributes and their levels for inclusion in the CE, it is important they be feasible and mirror actual contract designs. The specific attributes and their respective levels assessed in the CE were determined using results from the Phase I data collection and the other previously noted sources. Attributes are summarized in Table 2.1 and include: 1) price paid, 2) payment terms, 3) potential penalty, 4) contract length, and 5) buyer location. A sixth attribute, guaranteed buyer, was included as a reminder that selection of a contract guaranteed a buyer for their produce[14].

[Insert Table 2.1 Here]

To obtain welfare measures of the non-price contract attributes, a price term is needed. To reduce potential farm scale or crop production issues that could arise from surveying a diverse producer population, relative levels for *price paid* were selected following producer responses obtained during the qualitative interviews. Six levels were included in the experiment design: average price, 10% below average price, 15% below average price, 20% below average price, 25% below average price, and 30% below average price.

Payment terms describe the timing of payment once the product has changed ownership between the producer and buyer. For the majority of small-scale producers, on-farm sales, roadside stands, and farmers' markets comprise the bulk of their farm transactions, where a direct exchange takes place (Low and Vogel, 2011). Deferring

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[13] Hereafter these are referred to as "contract attributes".

[14] This attribute can be viewed as a pseudo-alternative-specific constant for the two contract options.

payment to a future period injects additional transaction and time costs, as well as risk. Three levels were used to describe payment terms: cash on delivery, 30 days, and 60 days.

Agricultural intermediaries (i.e., the buyer) also face difficulties when entering into a contractual agreement since they have imperfect information concerning the seller and the production process.[15] The potential for adverse selection and moral hazard on part of the producer places on the intermediary additional and unknown risks (Hueth and Ligon, 1999). To reduce such risks, contracts typically include an enforcement or penalty mechanism (examples may include produce quality, volume, or even delivery date specifications). In turn, this penalty inclusion places additional risk and potential costs onto the producer. The attribute potential penalty is included to represent such a mechanism. Due to the broad scope of possible contract violations, the potential penalty attribute was purposely left ambiguous. Three levels were used to describe potential penalty: 15% price decrease, 30% price decrease, and shipment refusal.

Contract length specifies the time period for which the contract is binding. A priori, the influence of contract length was uncertain, as arguments could be made about it having a positive or negative effect on contract participation utility. Contracts may introduce additional risks to producers by requiring long-term capital and infrastructure investments (MacDonald et al., 2004). For short-term contracts, the probability of entering into a contract where such investments are necessary is likely small. Conversely, participating in a long-term contract restricts management flexibility. The overall effect

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[15] Akerlof (1970) first considered the issue of imperfect (i.e., asymmetric) information in his now famous "Market for Lemons" paper.

of a contract's length is likely to be heterogeneous and vary by producer attributes. Levels 1 year, 3 years, and 5 years were used to describe contract length.

The attribute buyer location defines the location of the produce buyer in relation to the producer. Traditionally, small-scale producers have sold directly to consumers in local/direct markers (Low and Vogel, 2011). With a rise in consumer demand for locally grown produce, buyers wanting to capture a portion of this new market demand will be required to integrate these smaller producers into their business strategy. Therefore it is of benefit to buyers to better understand how producers value interacting with local versus non-local buyers. Whereas the previous attributes were continuous*,* buyer location is qualitative and entered as effects coded, with local being assigned as the base.[16]

Using the CE design software Ngene (version 1.1.2), a Bayesian efficient design was created, utilizing the D-optimality criterion (Sándor and Wedel, 2001). A total of sixteen choice scenarios were created (an example can be seen in Figure 2.1). To reduce possible response fatigue, the 16 scenarios were randomly blocked into two choice sets, with each set containing eight choice scenarios. Producers were randomly assigned a choice set.[17]

[Insert Figure 2.1 Here]

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[16] Effects coding solves for confounding intercept issues seen in dummy coding (Bech and Hansen, 2005).

[17] For the pilot survey, the five CE attributes were assigned vague prior assumptions, with *price paid* constrained to be positive, *payment terms*, *potential penalty*, and *buyer location* constrained to be negative, and *contract length* allowed to fall on either side of zero. Using conditional logit estimates obtained from 22 pilot surveys, informed priors were applied to the final CE design, with each attribute prior assigned a uniform distribution. To ensure no dominant alternatives existed, a dominance restriction was applied during the design process.

2.5 Data Analysis

2.5.1 Mixed Logit Regression Model

Following Revelt and Train (1998), analysis is carried out using the mixed logit model. More flexible than the conditional logit, the mixed logit model allows for individual taste variation, unrestricted substitution patterns, and correlation in unobserved factors over choice scenarios (Train, 2009). Relaxing the restrictions of the conditional logit, the indirect utility function shown in equation (1) can now be restated as:

$$U_{nit} = \boldsymbol{\beta}_n' \mathbf{X}_{nit} + \varepsilon_{nit}, \tag{3}$$

where $\boldsymbol{\beta}_n$ is the producer's specific parameter vector and *t* the choice scenario. Assigning ε_{ni} to be IID with an extreme-value (Gumbel) distribution, the conditional probability of producer *n* choosing marketing method *i* in choice scenario *t* is:

$$L_{nit} = \frac{e^{\boldsymbol{\beta}_n' \mathbf{X}_{nit}}}{\sum_{j \in C} e^{\boldsymbol{\beta}_n' \mathbf{X}_{njt}}}. \tag{4}$$

To gain a more complete understanding of producer contract preferences, each respondent was asked to answer several (8) choice scenarios. Letting *i(n,t)* denote the marketing method that producer *n* choses in scenario *t*, a producers' unconditional probability of a given sequence of choice scenarios is:

$$P_n(\boldsymbol{\theta}) = \int \prod_{t=1}^{T} L_{ni(n,t)t}(\boldsymbol{\beta}_n) f(\boldsymbol{\beta}|\boldsymbol{\theta}) d\boldsymbol{\beta}, \tag{5}$$

where $\boldsymbol{\theta}$ are coefficients (e.g., mean, standard deviation) describing the distribution of $\boldsymbol{\beta}$ that follows the density function $f(\boldsymbol{\beta}|\boldsymbol{\theta})$ (Hole, 2007). Following Revelt and Train (1998), the coefficients in equation (5) are estimated using the log-likelihood function:

$$\ln L(\boldsymbol{\theta}) = \sum_{n=1}^{N} \ln P_n(\boldsymbol{\theta}). \tag{6}$$

Because there is no closed form solution to equation (6), a simulation method must be used (Hole, 2007):

$$SLL(\theta) = \sum_{n=1}^{N} \ln\left\{\frac{1}{R}\sum_{r=1}^{R} P_n(\beta^r)\right\}, \tag{7}$$

where SLL is the simulated log-likelihood function and β^r is draw *r* from density $f(\beta|\theta)$. Five hundred Halton draws were taken as these draw types have been shown to improve efficiency over pseudo-random draws[18] (Train, 2009).

A major advantage of the mixed logit model is the capacity for attribute parameters to vary across the population, allowing for the identification of individual heterogeneity. In this study all contract attributes were designated as random and assigned a lognormal distribution, with the exception of the alternative-specific constant (*ASC*), assigned a normal distribution.[19] It is hypothesized and supported by Phase I findings that producers have mixed preferences for contract attributes beyond those explicitly examined herein. Thus a normal error distribution is assumed. The ASC is similar to the constant term found in other regression types and measures the change in utility received when choosing one of the two contract alternatives over the status quo.

In addition to heterogeneity, the mixed logit model allows for the testing of independently distributed versus correlated coefficients. Examining interdependence among the random attributes can provide a deeper understanding of the relationship (i.e., correlation) between attribute preferences. Allowing for correlation, the randomly drawn vector of β coefficients from equation (7) are now expressed as:

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[18] Halton draws provide distributional coverage more uniformly than random draws by inducing a negative correlation across observations, leading to a distribution's density that is represented more equally as the number of draws increases (Train, 2009).

[19] To ensure the proper sign and allow attributes to follow a lognormal distribution, *payment terms*, *potential penalty*, *contract length*, and *buyer location* were multiplied by -1.

$$\boldsymbol{\beta}_n = \mathbf{b} + \mathbf{L}\boldsymbol{\mu}_n, \tag{8}$$

where $\mathbf{L}$ is the lower-triangular Cholesky factor of variance-covariance matrix $\boldsymbol{\Omega}$, $\mathbf{b}$ is vector of population means, and $\boldsymbol{\mu}_n$ is a vector of independently distributed covariates (Revelt and Train, 1998).

2.5.2 Random Effects Regression Model

Mixed logit estimates provide the researcher with a distribution of WTP estimates based on the marginal rate of substitution between the monetary and non-monetary attributes. Although this provides a relative level of monetary preferences for one attribute (or attribute levels) over another, determinants of individual WTP estimates are unable to be obtained. While including individual characteristics as an interaction term with either the attributes (or attribute levels) or the alternative-specific constant identifies their respective effect on individual utility, both however fail to identify the factors influencing these WTP estimates (Campbell, 2007).

In order to gain a deeper understanding of the factors that drive producers' WTP for contract attributes (or attribute levels), a random effects model was used. This approach allows for the panel nature of the CE to be exploited (Campbell, 2007). Following Campbell (2007), an individual's WTP estimates for the ascribed contract attributes are pooled together, with the random effects model being:

$$WTP_{na} = \alpha + \mathbf{x}'_{na}\boldsymbol{\gamma} + \varphi_n + \varepsilon_{na}, \tag{9}$$

where the WTP of producer *n* for contract attribute *a* is determined by $\boldsymbol{\alpha}$, an intercept, $\mathbf{x}'_{na}$, a K-dimensional row vector of explanatory variables, $\boldsymbol{\gamma}$, a vector of producer and farm-level parameters to be estimated, φ_n, a producer specific effect, and ε_{nia}, an idiosyncratic error term.[20]

To proceed with the random effects model, producer-specific WTP estimates of the aforementioned contract attributes need to be obtained. Using the mixed logit model (equation (5)) in conjunction with Bayes' Rule, producer-specific contract attribute estimates are described in Train, (2009) as:

$$H_n(\beta_n | i_n, \theta) = \frac{L_{ni}(\beta_n) f(\beta | \theta)}{P_n(i_n | \theta)}, \tag{10}$$

where $H_n(\beta_n | i_n, \theta)$ is the distribution of β in the subpopulation conditional on choosing alternative *i* with coefficients θ, and $L_{ni}(\beta_n)$ is the producer's likelihood of making a particular choice given their specific β_n. Producer-specific WTP estimates of the four non-price attributes are recovered using the ratio of the indirect utility coefficient corresponding to each attribute and the price coefficient. Using these estimates, the random effects model is estimated using generalized least squares.

2.6 Results

Descriptive characteristics of the sample of SC producers surveyed are in Table 2.2. The average age of producers was 54.1, ranging from 20 to 87 years old. Seventy-one percent (71.4%) of the producers were male with 64.1% holding a college/university degree. In VA and NC, respectively, 66.0% and 57.8% identified farming as their primary occupation. This is 20.9% and 8.9% higher than each state's 2012 census findings, likely a result of survey sites, as full-time producers are more likely to attend grower meetings as well as belong to agricultural associations. Consistent with this result is producers'

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[20] A "balanced-panel" approach was used, requiring the removal of producers who did not answer all eight choice scenarios. A total of nine producers were removed.

farm income as a percentage of gross household income. Nearly the same percentage of producers in both states claimed farm income was 50% or more of gross household income, with 31.3% claiming that farm income makes up their entire household income. More than half of producers' gross farm sales in 2014 were less than $50,000, followed by 26.2% with gross farm sales ranging from $50,000 to $350,000. The primary marketing outlets were on-farm sales and sales at farmers' markets, respectively accounting for 34.2% and 28.3% of fruit and vegetable sales. Producers reported 21.0% of sales are marketed through a wholesaler/distributor/broker.

Food safety and product attribute certifications are also of increasing importance to buyers. Nearly thirty percent (29.4%) of producers claimed their farm is certified to the Good Agricultural Practices[21] (GAP) standard, with an additional 30.4% claiming a willingness to become certified if required by a buyer. In NC and VA, respectively 12.3% and 5.1% of producers reported being certified organic, with an additional 13.2% of NC and 23.2% of VA producers reported following organic methods without certification.[22]

[Insert Table 2.2 Here]

Descriptive statistics concerning producers' perceptions regarding buyer characteristics, contract attributes, and potential contract benefits, along with their likely use of contracts are presented in Tables 2.3 and 2.4, respectively. The five most important contract and buyer characteristics were identified to be Price Paid, Payment Terms, Buyer is Located Less Than 200 Miles from Your Farm, Contract Violation Penalties, and Quantity Requirements. It is worth noting that the standard deviations for these five

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[21] Conducted by the USDA Agricultural Marketing Service, this certification verifies best management practices for production, packaging, handling, and storage.

[22] Many uncertified organic producers cited certification costs and regulatory burden as reasons for not becoming certified.

characteristics are among the lowest of characteristics examined, implying significant agreement among producers. Also noted to be important was producer concern that using contracts would require them to relinquish control over farming decisions. This follows Hudson and Lusk (2004), who found the potential loss of autonomy to significantly decrease the acceptance of a contract scheme.

[Insert Table 2.3 Here]

Approximately twenty percent (19.6%) of producers stated they currently use contracts to sell some or all of their produce; importantly, however, another 30.7% indicated they would be interested in doing so. Nearly two-thirds (60.9%) of producers responded that contracts would be at least somewhat beneficial while 25.6% responded that contracts would be neither beneficial nor harmful. When asked what price discount they would be willing to accept in exchange for the security of a guaranteed buyer, responses ranged from zero to 65%, with the average price discount being 11.4%. Only 8.1% of respondents stated that they would be willing to accept more than a 25% price discount. For small-scale producers the ability to accept a reduced payment can be problematic in terms of generating enough income to cover operating expenses. Throughout both phases of this study, individual conversations with producers inevitably led back to the issue of pricing, with concerns being voiced about receiving "fair" pricing for their produce.

[Insert Table 2.4 Here]

2.6.1 Mixed Logit Results

Table 2.5 presents model results estimated from equation (7). Implementing the Swait-Louviere log-likelihood ratio test, the null hypothesis that regression parameters are equal across survey modes (i.e., paper vs. online) as well as across states (i.e., VA vs. NC) fails to be rejected, thus allowing for pooling of the datasets.[23] All contract attribute coefficients are found to be highly significant. Likewise, attribute standard deviations and the diagonal Cholesky matrix estimates are highly significant, indicating substantial preference heterogeneity among producer attitudes towards the structural framework of produce contracts. This suggests that producers have contrasting marketing interests with varying preferences towards contract structure. Following Hensher et al. (2005), the overall fit of the model was found acceptable, with a Pseudo R^2 of 0.237.

[Insert Table 2.5 Here]

2.6.2 Willingness-to-Pay Estimates

The sample distribution of attribute WTP coefficients from the mixed logit model is found in Table 2.6. With levels for the price paid attribute being defined in relative versus absolute terms, the WTP estimates are viewed as the percentage change in the contract price producers are willing to pay for a unit change in the attribute. All four non-price attributes had statistically significant mean WTP. The high level of attribute preference heterogeneity shown in the mixed logit results implies a high level of WTP preference heterogeneity. Thus, the mean WTP estimates should be viewed as an average result and not indicative of any single producer. In this analysis, with the four non-price attributes negatively affecting utility, the WTP estimate is interpreted as a willingness-to-accept (WTA) value.

[Insert Table 2.6 Here]

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[23] In addition, no significant differences were found in WTP estimates across survey modes as well as across states.

The mean WTA for delaying payment an additional day was found to be a 0.15% increase in the per-unit price paid. This implies structuring a contract that would postpone payment by 30 days would then require a price markup of 4.5% over a contract where payment is received upon delivery. Since the majority of sales of these producers are marketed through direct-cash transactions such as farmers' markets and on-farm sales, delaying payment increases risks associated with receiving the payment and increases the opportunity cost of money.

The mean WTA for a potential penalty increase of one percent was a 0.15% increase in the per-unit price paid. This is significantly lower than the 0.4-0.5% found in Vassalos et al. (2013). A reasonable expectation of this estimate would be to lie somewhere between 0 and 1, depending on the producers expected probability of a contract violation. While a contract penalty was found to be a highly important component of the contract structure, a value of 0.15% implies producers themselves are not overly concerned about causing any violations. This low value could also be due to the ambiguous definition of the attribute. During the qualitative interviews, producers were found to be most concerned over penalties regarding quantity requirements, where produce quality requirements, produce delivery dates and locations, and other potential penalty mechanisms were less of a concern. This is further supported in the quantitative surveys, with quantity requirements being seen as most important.

The results also indicate that producers are willing to accept, on average, a 4.57% increase in the per unit price they sell for one year increase in the contract length. In discussions with producers, extending the length of a contract to cover more than one growing season for the contracted crop was seen as a risk to potential future income as well as an encroachment on farm level autonomy. This was especially true among vegetable producers, where the ability to substitute and rotate between crops over multiple years is simpler than in fruit production. The high WTA value for annual increases in contract length indicates that the likelihood of a buyer and producer reaching a contractual consensus becomes doubtful the longer the contract is designed for.

The mean WTA to sell to a non-local buyer was found to be a 12.94% increase in the per-unit price paid. This also means that producers would be willing to accept a 12.94% decrease in per-unit price paid to sell to a local buyer. Freshness and appearance are two quality attributes that specialty crop buyers will typically demand, applying price or other forms of penalties for the lack of either. With many specialty crops being susceptible to bruising and other transportation-related damage, the farther produce travels from the farm gate the higher the likelihood that this damage impacts the price received. During the qualitative interviews, 76.9% of producers preferred to travel less than 100 miles to sell their produce, whereas 14.3% of producers stated they would not be willing to travel to deliver their produce to buyers. In both study phases, small-scale producers who currently use or have used contracts cited an unwillingness of buyers to travel to their farm to collect the contracted produce. The reason being that the quantity supplied was smaller than buyers were willing to travel to collect themselves. This in turn forced the producer to deliver the contracted produce, leading to additional transportation costs.

2.6.3 Random Effects Regression Results

Results from the random effects model are presented in Table 2.7. Designating buyer location as the base attribute, payment terms, potential penalty, and contract length entered the model as dummy variables. All else equal, producers were found to overwhelmingly accept a lower agreed upon contract price for changes in payment terms, potential penalty, and contract length relative to changes in buyer location. The similar effect payment terms and potential penalty have on the accepted contract price further suggests producers had comparable preferences for these two attributes, as the mean preference towards each attribute asked separately from the CE and shown in Table 3 were also found to not significantly differ from one another in either setting.

[Insert Table 2.7 Here]

A recent growth in CE literature has focused on respondent heuristics, such as ignoring one or more attributes when choosing among alternatives. This process is known as “Attribute Non-Attendance (ANA)” and can cause biased CE welfare estimates. To test whether ANA had a significant effect on the overall WTP estimate, producers were asked after completing the final CE scenario: “What contract features did you take into account when making your choice between contracts?” Under half (48.9%) of the producers stated that they ignored at least one contract attribute, with price paid, payment terms, potential penalty, contract length, and buyer location cited by producers as being applied into their choice decision 88.8%, 64.8%, 66.7%, 67.5%, and 65.2% of the time, respectively. The dummy variable Ignored Attribute was included to represent if a producer ignored one or more of the five contract attributes. While ignoring an attribute is a sign of violating the principles of rational preferences, no significant differences in WTP estimates was found between these two producer types.

Examining producer demographics, a significant difference between male and female producers was found to exist for an agreed upon contract price. Male producers were willing to accept a contract price on average 1.40% less than female producers. Producer's age was also found to significantly impact the contract price a producer was willing to accept, lowering the contract price demanded with age. An argument for this could be that older producers are more risk averse and willing to forego potential additional revenue in exchange for a secure buyer. Vegetable producers were found to demand a contract price on average 0.75% higher than non-vegetable producers. This is consistent with information gathered from individual producer discussions. Vegetable producers repeatedly stated greater concerns regarding the use of contracts, particularly the length of contracts and their effect on the decision-making capabilities to rotate between various crops to capture beneficial price changes. Further validating the pooling of producer surveys, no significant differences were found across states and survey modes for the contract price producers were willing to accept.

Farm income was included as a categorical variable, labeling as the base producers with a farm income of less than $150,000. To discern potential differences across multiple income ranges, two dummy variables were included: 1) $150,000-$349,999, 2) $350,000 or more. Both income groups are shown to be willing to accept a lower contract price than producers with a farm income of less than $150,000. As is the case for many small-scale producers, study participants report that the bulk of their farm sales came through direct-to-consumer sales. Results show that for each additional percent in total sales that come from direct-to-consumer interaction, the producer demands an additional 0.01% be added to the contract price.

To test the stability of producer's general attitude towards contracts, a dummy variable measuring the perception that the use of a marketing contract might have on a producer's operation was included. Producers who believed contracts would be harmful to their farming operation (negative contract perception*)* were found to require a 1.54% higher contract price than those who believed otherwise. While non-significance would not necessarily raise concerns, a significant positive effect of negative contract perception might suggest that producers were either randomly selecting alternatives or that their attitudes towards contracts were unstable throughout the survey. In what could be viewed as a "payoff" for marketing firms who incur expenses through communicating contract information to producers, those producers who received information from these firm types were willing to accept a 1.02% lower contract price than those who did not receive contract information from marketing firms.

A central argument in favor of contract use is the reduction of price, sales completion, and other forms of risk. Another means of risk reduction is for a producer to purchase food product liability insurance. Producers who currently carried this insurance required a 1.25% higher contract price than those without this coverage. A likely reason for this is that producers have spent time and money obtaining this insurance coverage and want to (partially) recoup this expense. Also, food product liability insurance reduces risk for not only the producer, but for the buyer as well. It stands to reason that producers understand this "benefit" that buyer's are freely receiving and demand additional compensation from them for it.

As noted earlier, food safety and product attribute certifications are becoming of increasing importance to buyers. Two standards that producers were queried on were GAP and Organic production. Producers who are GAP certified and those willing to become certified are found willing to accept a 1.23% and 1.45% lower contract price, respectively. While no significant difference in contract price was found for producers who are certified to grow organically, non-certified organic producers were found to be willing to accept a 1.36% lower contract price. In discussions with producers, higher costs and regulatory procedures were cited as significant hindrances in the certification process. The willingness to accept a lower contract price by producers who possess these certifications may be seen as a means to ensure that their efforts spent obtaining certification are met with the assurance of a guaranteed buyer.

While expressing concerns about specific aspects of contracts, producers overall were found receptive to the idea of using contracts as a viable marketing channel alternative. For small-scale SC producers the security of a guaranteed buyer will have to be met with tradeoffs, most likely in the form of lower per-unit pricing received. With the majority of SC producers located on small-scale farms and a strong agricultural sector in both states, potential efficiency and surplus gains for both contracting parties exist.

2.7 Conclusions

For their part, SC buyers are confronted with a supply industry which, at the large scale is increasingly concentrated, but which has recently experienced considerable growth among small-scale producers. This, combined with the current consumer interest in "locally grown" produce, challenges buyers to integrate new and oftentimes smaller suppliers than were part of their previous procurement networks. The purpose of this paper was to add to the limited literature relating to contract use among small-scale SC producers.

Surveying small-scale SC producers from two southeastern states, VA and NC, information concerning producers' use of contracts, preferences towards contract characteristics, and potential outcomes of contract use was collected. Due partly to under-developed SC markets, many small-scale SC producers employ direct-to-consumer marketing approaches. This marketing approach however imposes high transaction costs as well as exposes the producer to increased price, sales completion, and other forms of risk. Contracts have been identified as a way to mitigate these market imperfections and reduce the risks that small-scale SC producers face.

Producers were found to have mixed attitudes regarding the use of contracts. The largest concern dealt with the unit price paid that would be potentially received through a contractual agreement. Producers who marketed through direct outlets, such as farmers' markets where prices received are highest, had the largest reservations to adopting contracts. Producers who currently market produce to wholesalers and/or distributors, where prices are typically the lowest, were found to be most accepting to contract use. Despite price and other concerns, producers overwhelmingly believed that contracts would be beneficial towards their farming operation.

To gain a better understanding of the tradeoffs that small-scale SC producers were willing to make between contract attributes, a CE was conducted. Administering an extensive statewide (VA) pre-survey, contract attributes deemed critical by small-scale SC producers were identified. Appropriateness of the contract attributes selected was supported through a combination of producer contract perception rankings and highly significant CE estimation results.

Accounting for the heterogeneous nature of producers' preferences and the panel nature of the collected data (i.e. several choices from each producer), mean WTP estimates of contract attributes were recovered using a mixed logit model. To enter into a contractual agreement, producers required an increase in per-unit price for each of the four contract terms (attributes): 1) 0.15% per day that payment is delayed past date of delivery; 2) 0.15% for an additional percentage price decrease in potential penalties; 3) 4.57% for each year the contract is binding; and 4) 12.94% to sell to a buyer located more than 200 miles away.

Additionally, producer-specific WTP estimates were recovered and used in a random-effects model to determine factors driving producer WTP. Producers' views towards contracts had a considerable effect on WTP. Those viewing contracts in a negative manner demanded a 1.54% higher contract price compared to those with a more favorably view. A clear distinction in WTP between farm incomes was also shown, with higher farm income producers willing to accept a lower agreed upon contract price. Important to note for SC buyers, disseminating contract information to producers has a beneficial impact towards the contract price that buyers will pay producers. Producers who received information from marketing firms were found willing to accept a 1.02% lower contract price.

Information gained from this study can be used in improving the understanding of the buyer-seller relationship in terms of small-scale SC producers and their preferences towards contract adoption. By identifying contract attributes and buyer characteristics that are of importance to small-scale producers, along with recognizing those producers who are more accepting to the idea of marketing SC through contracts, buyers of SC can more efficiently target potential suppliers while also designing contractual terms to help meet both parties' demands and goals. This in turn can increase access to small-farm SC products and help the market more efficiently meet the increasing demands for such products.

In restricting this study to producers from two southeastern states, a more targeted survey approach could be taken. Because of this approach however, the findings are not necessarily transferrable to out of sample populations. Though results show that a contract design exists that satisfies small-scale SC producers' demands, any increase in contract use among these producers will also depend upon the demands of potential SC buyers. Further studies investigating buyers' preferences, particularly in these two southeastern states, would likely lead to a more complete understanding of the use of contracts in SC markets.

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Tables

Table 2.1. Choice Experiment Contract Attribute Description and Levels

Attribute	Description	Levels
Guaranteed Buyer[a]	There is a guaranteed buyer for your produce	Yes No
Price Paid	The per-unit average cash price you typically receive	Average 10% Below Average 15% Below Average 20% Below Average 25% Below Average 30% Below Average
Payment Terms	The timing of payment after delivery of produce	Cash on Delivery 30 Days 60 Days
Potential Penalty	The price penalty only if you fail to satisfy contract terms	15% Price Decrease 30% Price Decrease Shipment Refusal
Contract Length	The length, in years, of the contract	1 Year 3 Years 5 Years
Buyer Location	The location of the produce buyer from the farm gate	Local (<200 miles) Not Local (>200 miles)

Notes: [a] *Guaranteed Buyer* is assigned to act as the alternative-specific constant, measuring the change in utility of selecting a contract option over the status quo.

Table 2.2. Demographic and Farm Operation Characteristics of Producers and the Study Area

Characteristic	All Producers	VA & NC 2012 Ag. Census[a]	VA Producers	VA 2012 Ag. Census[a]	NC Producers	NC 2012 Ag. Census[a]
Characteristics of the Farm Operator						
Male (%)	71.4	85.3	72.0	83.4	67.3	87.1
Age	54.1	59.2	54.6	59.5	52.8	58.9
Education Level (%)						
Some High School	1.6	-	2.6	-	0.0	-
High School Degree	14.7	-	18.7	-	8.0	-
Some College/University	19.7	-	19.8	-	20.5	-
College/University Degree	64.1	-	58.8	-	71.4	-
Farming as Primary Occupation (%)	63.5	47.1	66.0	45.1	57.8	48.9
Years in Business	29.3	22.9	30.1	22.6	29.2	23.1
Characteristics of the Farm Operation						
Acres Farmed	199.7	173.7	129.2	180	349.8	168
Farm Gross Sales (%)						
< $50,000	55.0	82.0	55.1	85.0	56.2	79.2
$50,000 - $349,999	26.2	8.2	26.9	8.8	23.6	7.7
$350,000 - $999,999	12.8	5.1	12.9	4.3	13.5	5.9
> $1,000,000	6.0	4.6	5.1	1.9	6.7	7.1
Farm Income / Gross Income (%)						
< 25%	30.6	76.5	31.9	78.6	28.6	74.5
25% - 49%	8.6	7.1	8.9	7.3	8.3	6.9
50% - 74%	14.9	7.2	14.8	6.5	14.3	7.9
75% - 99%	14.6	4.7	14.8	4.0	14.3	5.3
100%	31.3	4.5	29.6	3.6	34.5	5.4
Specialty Crop Production (%)						
Fruits	63.3	-	63.3	-	63.2	-
Vegetables	64.4	-	62.4	-	66.4	-
Both	41.9	-	39.4	-	46.4	-
Production Practices (%)						
Organic – Certified	7.3	-	5.1	-	12.3	-
Organic – Not Certified	20.2	-	23.2	-	13.2	-
Integrated Pest Management (IPM)	32.6	-	31.4	-	35.8	-

Continued on next page

Characteristic	All Producers	VA & NC 2012 Ag. Census[a]	VA Producers	VA 2012 Ag. Census[a]	NC Producers	NC 2012 Ag. Census[a]
Production Practices (%)						
Good Agricultural Practices (GAP)	29.4	-	29.4	-	30.2	-
Willing to Become GAP Certified	30.4	-	27.3	-	36.8	-
Produce Sales Marketing Channel (%)						
On-Farm Sales	34.2	-	33.5	-	33.0	-
Farmers' Market	28.3	-	28.3	-	29.0	-
Wholesaler/Distributor/Broker	21.0	-	20.8	-	22.5	-
Direct Sales to Restaurant	3.9	-	2.2	-	7.0	-
Other	12.6	-	15.2	-	8.5	-
Producers Surveyed	381	-	213	-	152	-

Notes: [a] USDA NASS, 2012 Census of Agriculture, Specialty Crops, Vol. 2 Part 8

Table 2.3. Producer Perceptions of Buyer Attributes, Contract Benefits and Characteristics, and Potential Contract Outcomes

	Attributes/Benefits/Characteristics/Potential Outcomes	Mean[a]	S.D.[b]
If you were to enter into a contract, to what extent would the following **buyer attributes** be important to you?	Buyer is a Large Business	1.97	1.14
	Buyer is Located Less Than 200 Miles From Farm	3.92	1.25
	Buyer Has Been in Business 5 Years or Longer	3.07	1.27
	Buyer is Locally-Owned	3.28	1.28
	Buyer is Committed to Employee Health and Safety	3.51	1.18
	Buyer is Committed to the Environment	3.55	1.21
If you were to enter into a contract, how important would the following potential **contract benefits** be to you?	Less Price Risk	3.63	1.01
	Security of a Guaranteed Buyer	3.88	0.97
	Access to Credit	2.58	1.25
	Access to Education and Training	2.71	1.15
	Support in Understanding Food Safety Legislation	3.12	1.21
	Support in Implementing Food Safety Requirements	3.21	1.20
How important would the following **contract characteristics and potential outcomes** be in preventing you from entering into a contract?	Price Paid	4.29	0.76
	Payment Terms	4.00	0.86
	Quality Requirements	3.80	0.91
	Quantity Requirements	3.90	0.86
	Contract Violation Penalties	3.94	1.08
	Required to Grow a Specific Plant Variety	3.44	1.17
	Required to Use Harvesting Instructions	3.46	1.12
	More Intensive Production	3.42	1.09
	Less Ability to Pursue Other Markets	3.50	1.17
	Less Control of Farm Decisions	4.07	1.07

Notes: [a] Producers were given the option of choosing 'Not Important'(=1), 'Slightly Important'(=2), 'Moderately Important'(=3), 'Very Important'(=4), or 'Extremely Important'(=5).

[b] Standard Deviation

Table 2.4. Agricultural Contract Use and Information

		Mean[a]
Do you use contracts to sell any of your produce?	Yes	0.19
	No, but I did previously	0.06
	No, but I am interested in doing so	0.31
	No, and I am not interested in doing so	0.43
Overall, what is your perception of how produce contracts would affect your farm?	Greatly Beneficial	0.18
	Somewhat Beneficial	0.43
	Neither Beneficial nor Harmful	0.26
	Somewhat Harmful	0.08
	Greatly Harmful	0.05
What percentage (%) of your produce are you willing to sell through contracts?[b]		53.6 (30.9)
What per-unit sales price discount (%) are you willing to accept in exchange for a guaranteed buyer of your produce?		11.4 (10.5)
How many wholesalers/distributors/brokers are you aware of in your area that purchase produce from farms like yours?		4.7 (9.9)

Notes: [a] Standard Deviation in parenthesis

[b] Producers who responded “No, and I am not interested in doing so” to the question “Do you use contracts to sell any of your produce?” were not asked to complete this question.

Table 2.5. Panel Mixed Logit Estimation Results[a]

Attribute	*Mean Coefficient*	*Standard Deviation*				
ASC	3.162*** (0.392)	3.618*** (0.418)				
Price Paid	-2.567*** (0.196)	1.088*** (0.142)				
Payment Terms	-6.135*** (0.667)	2.455*** (0.434)				
Potential Penalty	-4.555*** (0.204)	1.284*** (0.147)				
Contract Length	-1.771*** (0.337)	1.914*** (0.272)				
Buyer Location	-1.060*** (0.295)	1.249*** (0.195)				
	Cholesky Matrix					
ASC	3.617***					
Price Paid	0.724***	-0.811***				
Payment Terms	0.550***	0.951***	2.195***			
Potential Penalty	0.420***	0.105	0.570***	1.066***		
Contract Length	-0.252	-0.121	0.374*	0.330*	1.827***	
Buyer Location	-0.524***	0.161	0.378***	0.533***	-0.310*	0.858***
Observations	6117					
Individuals	255					
Log Likelihood	-1470.90					
Pseudo R^2	0.237					

Notes: Standard errors are in parenthesis with statistical significance at the 10%, 5%, and 1% levels specified as *, **, and ***, respectively. Stata12 was used to estimate all models (StataCorp, 2011).

[a] Panel Mixed Logit model with correlated attribute coefficients using 500 Halton draws. Attributes assigned as random to follow a lognormal distribution, with exception of *ASC* that was designated as normal.

Table 2.6. Marginal Willingness to Pay Estimates

Attribute	WTP Calculation[a]	Mean WTP[b]	95% Confidence Interval[c]
Payment Terms	$\exp\left(\beta_{Payment} + \frac{1}{2}(\mu_{Payment})\right)/\exp\left(\beta_{Price}\right)$	-0.15***	-0.20 ~ -0.09
Potential Penalty	$\exp\left(\beta_{Penalty} + \frac{1}{2}(\mu_{Penalty})\right)/\exp\left(\beta_{Price}\right)$	-0.15***	-0.22 ~ -0.09
Contract Length	$\exp\left(\beta_{Length} + \frac{1}{2}(\mu_{Length})\right)/\exp\left(\beta_{Price}\right)$	-4.57***	-7.20 ~ -2.20
Buyer Location	$2 * \exp\left(\beta_{Local} + \frac{1}{2}(\mu_{Local})\right)/\exp\left(\beta_{Price}\right)$	-12.94***	-15.39 ~ -10.57

Notes: *** 1% significance, ** 5% significance, * 10% significance

[a] Following Carson and Czajkowski (2013) when both monetary and non-monetary attributes follow a lognormal distribution and constraining the standard deviation of *Price Paid* = 0. Each attribute's WTP estimate was multiplied by -1 to offset the previous adjustment of modeling the negative of the attribute, allowing for the lognormal attribute assignment.

[b] WTP estimates from Model 2, constraining the standard deviation of *Price Paid* = 0 to ensure fully defined ratios.

[c] 95% confidence intervals found using the Fieller method (Fieller, 1954).

Table 2.7. Random Effects Model WTP Estimation Results

Parameters	Coefficient	*St. Error*
Constant	-12.74***	2.429
Contract Attribute		
Payment Terms	12.65***	1.073
Potential Penalty	12.63***	1.074
Contract Length	9.00***	1.153
Ignored Attribute(s)	-0.49	0.507
Producer		
Age	0.03*	0.019
Gender	1.40**	0.698
College Educated	-0.42	0.510
Vegetable Producer	-0.83*	0.470
Virginia Producer	-0.51	0.587
Farm Income		
$150,000 - $349,999	2.12***	0.649
$350,000 or more	1.76***	0.588
Share of Total Sales From Fruit & Vegetables	-0.01	0.007
Share of Total Sales Made Direct to Consumer	-0.01***	0.005
Contract Use, Perception, and Information Source		
Currently Use Contracts	0.45	0.553
Negative Contract Perception	-1.57***	0.466
Received Information from Marketing Firms[a]	1.02**	0.528
Insurance and Certifications		
Food Product Liability Insurance	-1.33**	0.638
GAP Certified	1.16*	0.705
Willing to Become GAP Certified	1.36*	0.734
Organic Certified	-0.17	1.117
Organic Non-Certified	1.28*	0.784
Online Survey	-0.09	0.495
σ_{μ}^2	0	
σ_{ε}^2	8.27	
R^2	0.321	
Wald X^2 (22)	486.13	
Number of Observations	872	

Notes: *** 1% significance, ** 5% significance, * 10% significance

[a] e.g., Wholesalers, Brokers, etc.

Figures

*Imagine a buyer offers you a choice between 2 produce contracts. Consider the options carefully and make your choices as if they are real. Other than the information given, assume the contracts are identical in all other aspects. If you choose not to select either of the 2 contract options, please choose the "Neither" option. Please choose the option you **most prefer**. Below is an example.*

Example: Which contract would you choose from the options below? (*Check only one*)

Attributes	**Contract A**	**Contract B**	**Neither**
Guaranteed Buyer	Yes	Yes	
Price Paid	Average	10% Below Average	
Payment Term	Cash on Delivery	60 Days	
Potential Penalty	30% Price Decrease	15% Price Decrease	
Contract Length	5 Years	1 Year	
Buyer Location	Local	Not Local	
I would choose:	☐	☐	☐

Use the attribute definitions below to help you answer the following questions.

a) Guaranteed Buyer – There is a guaranteed buyer for your produce

b) Price Paid – The per-unit sales price

Options

- **Average** – the average **CASH** price you typically receive
- **10% below average price**
- **15% below average price**
- **20% below average price**
- **25% below average price**
- **30% below average price**

c) Payment Term – The terms of payment

Options

- **Cash on delivery**
- **30 days**
- **60 days**

d) Potential Penalty – The penalty **ONLY** if you fail to satisfy contract terms

Options

- **15% price decrease**
- **30% price decrease**
- **Shipment refusal** – produce buyer refuses to purchase produce

e) Contract Length – The length of the contract

Options

- **1 year**
- **3 years**
- **5 years**

f) Buyer Location – The location of the produce buyer

Options

- **Local** – buyer is located less than 200 miles from your farm
- **Not Local** – buyer is located more than 200 miles from your farm

Figure 2.1. Choice Experiment Introduction and Scenario Example

3 Biofuel Policies: The Underground Limitations on Biofuels, NPK

3.1 U.S. Biofuel Policies

"A smooth transition to a larger national biofuels program will require additional planning and policy analysis to avoid unintended consequences that might result from large-scale production and use of bioenergy in the United States." (Alvarez et al. 2010)

U.S. energy policy has seen a dramatic shift toward renewable fuels within the last 10 years. For economic, geopolitical, and environmental reasons, biofuels are considered an attractive alternative for meeting domestic energy demands (Hurtley 2009). Public policies such as the Energy Policy Act of 2005 (EPAct) and the Energy Independence and Security Act of 2007 (EISAct) have increased domestic biofuel production through the use of mandatory blending targets, tax exemptions, subsidies, and tariffs on imported biofuels (Sorda et al. 2010). With mandatory blending targets set by the revised Renewable Fuel Standard (RFS2), a guaranteed market has been created for biofuel producers.

While much research has been conducted in regards to U.S. biofuel policies, a significant arena of debate has been neglected. A key argument in favor of domestic biofuel production is that it is a renewable path towards energy independence. However the inputs used in the production of biofuel feedstock, primarily fertilizer nutrients, are anything but renewable. The extensive use of non-renewable inputs calls into question the renewability of biofuel production. Serious tradeoffs regarding fertilizer nutrient use for the production of biofuels need to be more thoroughly examined. This paper will discuss the possible impacts that U.S. biofuel policies may have on energy security by potentially trading one international dependency for another. Specifically, this paper will examine the effects that U.S. biofuel mandates may have on the sustainability of domestic fertilizer supply and demand.

The remainder of this paper is arranged as follows: Sections II and III describe the demand and supply markets for U.S. fertilizer. This is followed by an analysis of the demands placed on these markets by the existing U.S. biofuel policies under different crop use scenarios. The final section presents a discussion of the findings and resulting conclusions.

3.2 U.S. Fertilizer Demand

"Upon this handful of soil our survival depends. Husband it and it will grow our food, our fuel, and our shelter, and surround us with beauty. Abuse it and the soil will collapse and die, taking man with it." (from Sanskrit literature, 2000-1500 BC; Johnson and Dawson 2005)

The success of the U.S. agricultural industry over the last half century has been unrivaled by any other nation. In 2009 U.S. farm output was 170 percent above 1948 output, growing at an average annual rate of 1.63 percent (USDA ERS[a]). While prime farmland and genetic engineering have been major contributors to this feat, the use of inorganic, industrially produced fertilizers has been a key factor in enabling the enormous increase in food production over the last five decades (Matson et al. 1997).

Historically, farmers practiced crop rotation and applied manure from farm animals to supplement their fertilizer needs. Today, modern agriculture has become highly dependent upon manufactured fertilizers to achieve optimum yields (McLaughlin et al.

2000). Using today's average per capita food supply with the 1900 level of agricultural productivity, roughly 2.4 billion people or just 40% of today's total population could be fed (Smil 1999). With each crop's harvest, vital nutrients are removed from the soil. If these lost nutrients are not returned, either through organic or inorganic means, the high yields that modern agriculture has become accustomed to will no longer be sustainable.

Plants require 3 primary nutrients: Nitrogen (N), Phosphorous (P) and Potash (K). From 1960 through 2011, U.S. agricultural fertilizer use of these 3 primary nutrients nearly tripled, increasing from 7.5 million nutrient tons to 21.8 million nutrient tons. Over this 50 year period, N use increased approximately 475%, from 2.7 to 12.8 million nutrient tons; P use increased from 2.5 to 4.3 million nutrient tons, an increase of 170%; and K use increased from 2.1 to 4.6 million nutrient tons, an increase of nearly 225% (USDA ERS[b]).

Under current biofuel policy, U.S. agricultural producers have been given the unique opportunity to play an important role in reaching the renewable fuel benchmarks. Crops such as corn, soybeans, sugarcane, sugar beets, wheat, grain sorghum and barley can all be used to produce biofuel. The renewable fuel volume requirements for 2013 can be seen in Table 3.1. Current legislation caps "Conventional" biofuel at 15 billion gallons per year from 2015 to 2022 while "Advanced" biofuel increases each year up to 21 billion gallons in 2022. Future revisions could change these requirements just as the EISAct revised the initial requirements set forth in the EPAct.[24]

[Insert Table 3.1 Here]

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[24] "As part of this process, EPA announced that it would issue a notice of proposed rule-making each spring and a final rule by November 30 of each year to set the renewable fuel standard for each ensuing year. Pursuant to this task, the EPA Administrator has the authority to waive the RFS requirements, in whole or in part, if, in her determination, there is inadequate domestic supply to meet the mandate." (Schnepf and Yacobucci, 2012)

Contingent upon the feedstock chosen to meet these new fuel standards, the potential impact on the U.S. demand for fertilizers could be significant. Integer (2007) forecasted that U.S. fertilizer demand from biofuel crop production would reach 2.6 million nutrient tons in 2012, over 10% of U.S. fertilizer demand. Our "back of the envelope" calculations will show that this is a significant underestimation of biofuel's share of domestic fertilizer demand.

3.3 U.S. Fertilizer Supply

Liebig's law of the minimum: "The rate of growth of a plant, the size to which it grows, and its overall health depend on the amount of the scarcest of its essential nutrients that is available to it."(Allaby 2004)

Nordhaus (1974) described the history of the American economy as a "Cowboy" economy in which agricultural land could be acquired at an approximately fixed cost, the environment could be used as a sink without any significant degradation caused to it, and the supply of many critical minerals was abundant and at high grades. For better or worse this style of economy is no longer sustainable. Adjusting for inflation between 1990 and 2010, average farm real estate values have doubled (Nickerson et al. 2012). America's environmental carrying capacity is reaching its limits; the degradation of the Chesapeake Bay being one of the better-known examples. The supply of important minerals have declined and decreased in quality (Cordell et al. 2009). The long-term availability and quality of the most essential minerals to U.S. agriculture: N, P, and K, may no longer be as secure as many have previously thought.

3.3.1 Nitrogen

Nitrogen is one of the most abundant elements on earth accounting for nearly 80%

of the atmosphere. With every breath of air taken nitrogen is inhaled. Regrettably for the majority of crops this freely available and essential element is not accessible in its natural form. Using a technique called the Haber-Process, nitrogen is produced into a readily accessible form. This conversion process however requires large amounts of fossil fuel, with natural gas accounting for 75-80% of the feedstock used in all N manufactured fertilizer (Fixen and Johnson 2012). This causes N production to represent the largest share of energy consumption of all inorganically manufactured fertilizers and account for approximately 1.5% of U.S. natural gas consumption (McLaughlin et al. 2000).

Advancements in production technologies and shale gas discoveries have vastly increased the U.S.'s known natural gas reserves. At the end of 2011, U.S. reserves stood at 349 trillion cubic feet with a reserve base of 2,384 trillion cubic feet (U.S. EIA). With domestic supply and extraction rates remaining constant at the 2011 level[25], U.S. reserves will be depleted in under 15 years and the reserve base in less than 95 years.

The recent increase in natural gas reserves should help reduce America's dependency on energy imports and will presumably lead to higher amounts of domestic nitrogen fertilizer production. Nevertheless, the fact remains that natural gas is an exhaustible resource and the depletion of it reduces our ability to efficiently produce nitrogen fertilizers. Dawson and Hilton (2011) estimate that without the application of inorganically manufactured nitrogen fertilizer, only half of the global population could be supplied with an adequate amount of foodstuffs.

3.3.2 Phosphorous

Dubbed "Life's Bottleneck" by Asimov (1959) due to the vital role it plays in

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[25] In 2011, 24.4 trillion cubic feet of natural gas was extracted. 2011 is most current estimate available.

sustaining all life, phosphorous is a non-renewable natural resource with no known substitute. The 11th most abundant element in the earths crust, the soils in which plants are grown generally contain only small amounts in a readily available form (Syers et al. 2011). To compensate for this inadequacy, agricultural producers have turned to manufacture-based phosphate fertilizers produced from phosphorous rock and ore.

Along with being one of the world's largest consumers, the U.S. ranks second globally in mining phosphate rock. In 2013, 6 U.S. firms operating at 11 mines produced over 32 million metric tons of phosphate rock (USGS 2014). This production allowed the U.S. to meet nearly 95% of its 2013 domestic phosphate demand (USGS 2014). U.S. phosphate deposits are highly concentrated with 85% of production coming from only 2 states, Florida and North Carolina. Although large quantities of phosphorous are found in North Carolina, they are located in environmentally sensitive areas causing restrictions to be placed on much of the states extractable resources (Vaccari 2009).

Estimates of U.S. reserves stand at 1,100 million tons with a reserve base of 3,400 million tons (USGS 2014).[26] With domestic supply and extraction rates remaining constant at the 2013 level, U.S. reserves will be depleted within 40 years and the reserve base within 120 years. Stated by Asimov (1974) in the clearest of terms: "Life can multiply until all the phosphorous is gone and then there is an inexorable halt which nothing can prevent."

3.3.3 Potash

Potash serves many dynamic roles in crop production, including increased yield and

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[26] The reserve base includes all resources whose extraction is currently economic (reserves), marginally economic (marginal reserves) and subeconomic (subeconomic resources). Through advancements in production practices, increases in the costs of production and/or the depletion of higher-grade ore, marginal reserves and subeconomic resources may convert into economic reserves.

water retention, disease and pest resistance, reinforcement of roots and stems, and increased uptake of nitrogen and phosphate. Manufactured solely from geological sources, there are no fertilizer substitutes for potash that are economically feasible.

In 2013 U.S. potash production reached nearly 1 million metric tons. Domestic consumption totaled 5.5 million metric tons, causing the U.S. to depend on imports for over 80% of its demand (USGS 2014). The USGS estimates that domestic reserves sit at 200 million metric tons with a reserve base of 300 million metric tons (USGS 2014). With domestic supply and extraction rates remaining constant at the 2013 level, U.S. reserves will be depleted in approximately 220 years and the reserve base will be depleted in 330 years. A constant rate of extraction is unlikely to happen, as extraction will presumably increase to meet the rising demand of a growing population and increased biofuel production. Domestic production and supply for NPK can be seen in Tables 3.2 and 3.3.

[Insert Table 3.2 Here]

[Insert Table 3.3 Here]

NPK separated by industry usage can be seen in Table 3.4. For all 3 primary nutrients, the fertilizer industry consumes the vast majority of mined production. Thus the cost of any reduction in the supply of these nutrients will be borne almost entirely by the fertilizer industry, which in turn will be passed on to agricultural users. Relying almost solely on fertilizer demanding crops, specifically corn, a reduction in crop output will limit the capability of U.S. biofuel production.

[Insert Table 3.4 Here]

3.4 U.S. Biofuels Fertilizer Demands

"Corn is currently the dominant biofuels feedstock and will likely remain so in the future even with every intention of commercializing alternatives." (PNC 2010)

The RFS2 separates biofuels into four classes – Conventional, Advanced, Biomass-based Diesel, and Cellulosic – with each class having its own specific volume requirement. This section will investigate the fertilizer demands of various crops used to produce the different classes of biofuels and their potential impact on the domestic fertilizer supply base.

3.4.1 Conventional Biofuel (Cornstarch)

Approximately 90% of U.S. biofuel consumption comes from ethanol, with cornstarch-based ethanol accounting for over 90% of all ethanol produced.[27] Current technology allows for the production of 2.77 gallons of ethanol per bushel of corn. Over the last 5 years U.S. corn production has averaged 149.4 bushels per acre. Thus, the average acre of corn is able to produce 414 gallons of ethanol (Table 5). If the 2013 mandatory blend limit of 13.8 billion gallons were reached using solely corn, 4.98 billion bushels would be needed.[28] This would have required 36% of the 2013 U.S. corn yield. With corn alone consuming nearly half of the nation's nutrient use, cornstarch-derived ethanol exacts a heavy toll on America's domestic supply of N, P, and K.

Using recent fertilizer data, the average U.S. acre of corn receives 140 lbs N, 60 lbs P, and 79 lbs K (USDA ERS^c). With a 5-year average yield of 149.4 bushels per acre, U.S. corn demands 0.94 lbs/bu N, 0.40 lbs/bu P, and 0.53 lbs/bu K. At 2.77 gallons of ethanol per bushel of corn, reaching the mandatory blend limit would require 2.3 million

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[27] Hence, approximately 80% of U.S. biofuel production is derived from cornstarch.

[28] (Mandatory Blend Limit of Ethanol) / (Gallons of Ethanol Per Bushel) = (Total Bushels Needed)

nutrient tons N, 1.0 million nutrient tons P, and 1.3 million nutrient tons K. This equates to 25% of domestically produced N, 9% of domestically produced P and 109% of domestically produced K. Total demand of domestic nutrient production equates to 22%. Total area needed would be 33.4 million acres, which equates to 8% of total U.S. cropland[29]. With the blending mandate increasing to 15 billion gallons in 2015 through 2022, the share of nutrients used to produce cornstarch-derived ethanol can be expected to increase.

[Insert Table 3.5 Here]

3.4.2 Advanced Biofuel

To be classified as an "Advanced" biofuel, production must come from a non-corn feedstock and reduce greenhouse gas emissions by 50% relative to gasoline. A fuel that meets the criteria for "Advanced" likewise meets the criteria for "Conventional" and may be used toward the overall blending mandate. In 2013, the RFS2 blending mandate required a minimum of 2.75 billion gallons of "Advanced" biofuel. This biofuel type is separated into multiple categories, each with its own fuel requirement: 1.92 billion gallons of biomass-based biodiesel[30], 6 millions gallons of cellulosic biofuel and 824 million gallons of any other biofuel that fits the "Advanced" biofuel definition. Grain sorghum, wheat, barley, sugarcane, sugar beets, soybeans, canola, sunflower, camelina, and others qualify as potential feedstock for "Advanced" biofuels. Using the same method and formulae as shown above for "Conventional" biofuels, "Advanced" biofuel

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[29] Nearly 406 million acres, 18% of U.S. land, falls under the land use category of "Crop land." (Nickerson et al. 2011)

[30] Per RFS2 guidelines, a gallon of biodiesel is given a volumetric adjustment equal to 1.5 gallons of ethanol. Thus the requirement of 1.92 billion ethanol equivalent gallons is equal to 1.28 billion gallons of actual biodiesel.

crop types along with their resulting nutrient demands under the assumption that they were to fulfill the entire 2013 RFS2 guidelines can be seen in Table 3.5.

The results are sobering. For wheat, while the share of P remains similar to that of corn and K reduces to 19%, the percentage of cropland required increases significantly to 29%. Similar findings are shown for barley. Sugar cane and sugar beets appear to perform the best in terms of "nutrient efficiency" for N and P and would require the smallest amount of dedicated cropland. However, sugar cane production is limited to warmer climates and is currently produced in only 4 states, while sugar beet production is limited to a cooler climate and is currently produced in Midwest and North Pacific states. While the initial nutrient production demands look promising for biodiesel produced from soybean, canola, and sunflower, it is important to remember that these results account for less than 10% of ethanol production. These results say nothing about the potential impact of competing uses amongst crop types and is left for future studies.

3.4.3 Cellulosic Biofuel

While there are over 200 commercial scale conventional biofuel plants in the U.S. producing predominately corn-based ethanol, there are yet to be any commercially scaled plants producing cellulosic biofuel. The primary reason for this is the economics associated with producing cellulosic biofuel. Current production costs of cellulosic biofuel far surpass those of corn-based ethanol and gasoline. There have been substantial advancements however, with the cost of producing cellulosic biofuel decreasing nearly four-fold since the early 1980's, (Wyman 2001).[31]

Even with these cost reductions, the EPA has been forced every year since the

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[31] These reductions have been shown at "Pilot" scaled plants only. "Pilot" scaled plants are capable of producing only minimal amounts of biofuel. Similar cost reductions have not been proven at the "Commercial" plant level.

mandate began in 2010 to reduce the mandate amount due to a lack of feasible production. In 2013, only 6 million gallons of the original 1 billion gallon production mandate was enforced. This equates to just 0.6% of the original mandate! Due to this low volume of production, fertilizer demand from cellulosic biofuel will not be discussed.[32]

3.5 Conclusion

"We stand, in most places on earth, only six inches from desolation, for that is the thickness of the topsoil layer upon which the entire life of the planet depends." (Sampson 1981)

For years America's dependency on energy imports, specifically oil, has been called our nations "Achilles' Heel". Due in part to both economic and social incentives, policymakers have begun to take steps to reduce this dependency. The increased use of domestically produced biofuels has been seen as a partial answer to our "addiction" to foreign oil imports. With U.S. biofuel production relying on grown organic matter, maintaining soil fertility will be crucial in meeting these new renewable energy demands.

U.S. biofuel demand requirements will continue to rise through 2022, thus placing a larger burden on American agricultural lands. Without replenishing the nutrients consumed by the crops grown or lost due to erosion, the soil quality will be negatively affected and biofuel production efficiency diminished. Amid limited domestic resources, America will be required to either import these additional nutrient demands or increase its domestic production, thus hastening the depletion of domestic reserves. With decreasing amounts of nutrients being concentrated in only a handful of countries, some with unstable and unfriendly governments, being heavily reliant on nutrient imports has

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[32] For preliminary fertilizer demands from cellulosic biofuel production, please contact the author.

the potential for adverse geopolitical consequences. For example, nearly 75% of the global phosphate reserves are found in Morocco and Western Sahara where territorial disputes have been taking place for over 3 decades. Also, Russia controls significant shares of the world's natural gas and potash, and has recently shown its willingness to use these resources, specifically natural gas, to exert its global influence. America needs to ensure that it's renewable fuel policies are not just simply trading one international dependency for another; i.e. Oil for Fertilizer Nutrients.

With simple "back of the envelope" calculations, this paper has shown that the U.S.'s current biofuel policy is heavily dependent on non-renewable nutrient inputs. Thus the question needs to be asked, "How renewable are the current plant-based biofuels?" At present, corn is the predominant feedstock in U.S. biofuel production accounting for approximately 80% of all biofuel produced. The nutrient demand for corn to produce the entire 2013 RFS2 mandate of 13.8 billion gallons would actually require the importing of Potash and consume over a quarter of the domestic production of Nitrogen. This is a significant blow to one of the main biofuel policy objectives of energy independence. While other crops such as grain sorghum require considerably less nutrient inputs, the land requirement to meet the RFS2 standards would require a substantial portion of the available cropland. These results suggest that biofuels as a renewable alternative to oil imports is not as straightforward as some might argue.

Considerable research has been conducted on the different aspects surrounding biofuel production. Determining the economic and energy efficiency of different biofuel feedstock as well as the ethical issue of using food for fuel has given rise to much debate. The goal of this paper was to look at the potential supply and demand effects of biofuel production on domestic nutrient reserves. Just like petroleum, these nutrients are non-renewable resources and once depleted will be unavailable for future needs. With the global population projected to increase to 9 billion by 2030 coupled with an expected increase in U.S. energy demands, American agriculture will continue to be called upon to play a vital role in providing sustenance and energy to these growing global needs. With modern agriculture relying so heavily on non-renewable fossil fuel based fertilizers, it is important that we wisely use these dwindling and finite resources.

Many questions surrounding biofuel production remain unanswered. Further research is needed to determine the efficiency with which different biofuel feedstock use these limited nutrient inputs. Is the soil composition in certain regions better suited for specific biofuel crops that would require little to no nutrient inputs? What impact will an increase in the global demand for energy have on biofuel feedstock? With an increase in biofuel energy demand, additional application of nutrients will be necessary. An increase in demand coupled with a decrease in supply will cause nutrient prices to rise. With feedstock costs accounting for nearly 70% of the total costs of biofuel, will this rise in price cause biofuels to become economically unfeasible compared to gasoline? With plant growth dependent upon the healthiness of the soil, it is essential that our non-renewable nutrient resources be strategically applied and conserved for future generations.

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Tables

Table 3.1. 2013 Minimum RFS2 Requirements

Biofuel	Gallons
Cellulosic	6 million
Biomass-based Biodiesel	1.92 billion
Advanced	2.75 billion
Renewable	16.55 billion

Note: 2013 EPA RFS2 final rulemaking

Table 3.2. U.S. Nutrient Production 2009 - 2013

Year	Nitrogen	Phosphate Rock	Potash
2009	7,700	26,400	720
2010	8,290	25,800	930
2011	9,350	28,100	1,000
2012	8,730	30,100	900
2013	8,700	32,300	970
Average	8,554	28,540	904

Note: In thousand metric tons

Table 3.3. U.S. Nutrient Supply

Nutrient	Reserve	Reserve Base
Nitrogen[a]	349 (14)	2,384 (94)
Phosphate Rock[b]	1,100,00 (39)	3,400,000 (119)
Potash[b]	200,000 (221)	300,000 (332)

Note: Years remaining in parenthesis

[a] Measured in trillion cubic feet; assuming all N is produced from natural gas

[b] Measured in thousand metric tons

Table 3.4. Industry Use of Domestically Produced Primary Nutrients

Use	Nitrogen[a]	Phosphorous[b]	Potash[a]
Fertilizer Industry	≈ 86%	≈ 80%	≈ 85%
Chemical Industry	≈14%	≈ 20%	≈ 15%

[a] USGS Mineral Commodities Summary 2014

[b] Heffer et al. (2006)

Table 3.5. 2013 RFS2 Nutrient and Crop Land Demand by Feedstock

	Corn[a]	Grain Sorghum[b]	Wheat[b]	Barley[b]	Sugar Cane[b]	Sugar Beet[b]	Soybean[c]	Canola[c]	Sunflower[c]
Biofuel Mandate	13,800	14,624	14,624	14,624	14,624	14,624	1,280	1,280	1,280
Gallons per Unit	2.77	2.77	2.71	2.5	19.5	24.8	1	1	1
Unit	Bushel	Bushel	Bushel	Bushel	Ton	Ton	7.7 lbs oil	7.7 lbs oil	7.7 lbs oil
Yield per Acre	149	61	46	70	34	27	479	653	584
Gallons per Acre	414	169	124	174	667	670	62	85	76
N lbs/Acre	140	54.3	55.9	61.9	100	106	2.9	100	22.3
P lbs/Acre	60	14	19.2	20.4	40	65	14.3	23	8.9
K lbs/Acre	79	1.4	3.8	6.7	80	38	20	30	8.9
Biofuel Gallons per Nutrient Pound									
N	3.0	3.1	2.2	2.8	6.7	6.3	21.5	0.8	3.4
P	6.9	12.1	6.4	8.5	16.7	10.3	4.4	3.7	8.5
K	5.2	120.7	32.5	26.0	8.3	17.8	3.1	2.8	8.5
2013 RFS2 Mandate Domestic Nutrient Production Demand									
N	25%	25%	35%	28%	12%	12%	0%	8%	2%
P	9%	5%	10%	8%	4%	6%	1%	2%	1%
K	109%	5%	19%	23%	72%	34%	17%	19%	6%
2013 RFS2 Mandate Crop Land Demand									
% of Crop Land	8%	21%	29%	20%	5%	5%	5%	4%	6%

[a] Conventional Biofuel: 2013 RFS2 requirement of 13.8 billion gallons

[b] Advanced Biofuel: 2013 RFS2 requirement of 13.8 billion gallons of "Conventional" biofuel plus 824 million gallons of "Advanced" biofuel

[c] Biomass-based Biodiesel: 2013 RFS2 requirement of 1.92 billion ethanol equivalent gallons (1.5 gallons of ethanol : 1 gallon of biodiesel)

4 A Decade of Demand: Fertilizer Nutrients and Cropland Inputs Used in Corn Ethanol

4.1 Introduction

Biofuels are being looked at as a geopolitical, environmental, and economic means to transition away from petroleum based fuels (Hurtley, 2009). The aim of U.S. biofuel policy is structured around three separate but interlinked goals: 1) Energy security; 2) Reduction of greenhouse gas emissions; and 3) Economic development of the rural economy. While all three goals are worthy of discussion, this paper will be looking at the effects that U.S. biofuel policies are potentially having on domestic energy security and whether the U.S. is trading one mined dependency for a different mined nonrenewable mineral. Specifically, this paper will discuss the demands that corn starch-derived ethanol production has placed on U.S. nutrient fertilizer production and cropland over the last decade and the resulting shift in the domestic supply-demand balance.

With the recent authorization of multiple renewable fuel policies (the Energy Policy Act of 2005 and the Energy Independence and Security Act of 2007 for example), biofuels have been brought to the forefront of the U.S. energy policy discussion.[33] With a principal policy objective being to increase domestic biofuel production, a renewable fuel standard (RFS) was created, imposing annual consumption mandates for biofuel. The annual RFS mandate is a combination of ethanol and bio-diesel biofuel.[34] Beginning in 2006, a RFS mandate of 4.0 billion gallons was implemented and has steadily increased. In May 2015 the EPA proposed decreasing the original 2014-2016 RFS mandate to

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[33] Readers are encouraged to read Duffield et al. (2008) for a review of U.S. biofuel policies over the last 50 years.

[34] For more detailed information regarding the RFS, please read “Renewable Fuel Standard”: http://www.epa.gov/otaq/fuels/renewablefuels/index.htm.

18.15, 20.5, and 22.5 billion gallons of biofuel for 2014, 2015, and 2016 respectively. This reduced blending target is aimed to adjust to the ethanol "blend wall"[35] as well as the lack of advanced biofuel production capability. Current RFS mandates are set through 2022, where 36 billion gallons of biofuel is currently mandated.

While virtually any crop may be used to produce biofuels, a small number of crops dominate U.S. production. Due to technological limitations and production capabilities, as well as economic feasibility, the primary domestic biofuel produced is corn starch-derived ethanol. Corn has consistently accounted for roughly 90% of all U.S. ethanol production, with grain sorghum coming in at a very distant second (UIE, 2009). With ethanol accounting for approximately 90% of the domestic biofuel produced, it is easy to see how dominant corn's role is in the national biofuel conversation.[36] To promote other biofuel types, RFS mandates have set maximum allowable quantities of corn starch-derived ethanol (see Table 4.1) (US EPA, 2015).

[Insert Table 4.1]

With a central argument in favor of domestic biofuel production being a renewable path towards U.S. energy independence, a fundamental requirement of both renewability and energy independence has been overlooked. The inputs used for biofuel, e.g., crops, are major consumers of non-renewable inputs, e.g., nutrient fertilizers and land[37]. Over the last decade in the U.S., corn production alone has consumed nearly 50%

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[35] The "Blend Wall" refers to current regulations that set a maximum blending limit of ethanol to gasoline not to exceed 10%. A decrease in domestic gas consumption coupled with increases in vehicle fuel efficiencies have caused various lobbying groups to call for proposals raising the maximum blending limit to 15 and even 20%.

[36] Therefore, corn starch-derived ethanol accounts for approximately 80% of domestic biofuel production: (~90%)×(~90%)≈80%.

[37] It is well accepted that nutrient fertilizers are produced from nonrenewable resources. What is not as generally accepted is the definition of land being either renewable or nonrenewable. Throughout the rest of this paper, land will be

of all agricultural fertilizer and more than 20% of cropland in production (USDA ERS[a], 2015). The volume of these non-renewable inputs used in crop production casts doubt on the actual "renewability" of such fuels and the ability to achieve true energy independence.

Much research has been conducted surrounding biofuel production and the impacts from various policy scenarios. This paper hopes to add to the discussion surrounding biofuel policies by asking an important question that has not received the attention it deserves: "*What about the non-renewable inputs (e.g., fertilizers and cropland) that go into producing the inputs (e.g., corn) used for biofuel production?*" The impacts and tradeoffs associated with the use of such non-renewable inputs warrant a more thorough examination. When non-renewable resources are present, markets are prone to failures. Private users do not necessarily make the socially optimal decision regarding non-renewable resource use. This inefficient use of resources can lead to faster than optimal extraction rates hastening the depletion of its in-situ stock.

This paper examines the fertilizer demands placed on domestic U.S. nutrient production as well as cropland requirements from corn starch-derived ethanol production since the implementation of the RFS in 2006. The methods used in this study can easily be applied to additional crops as well as biodiesel production. While the analysis used is quite simple and direct, the results are unsettling to the claims of both renewability and energy independence, as corn starch-derived ethanol alone has demanded nearly 80%, 25%, and 10% of domestic potash and nitrogen production and cropland respectively.

This paper is arranged as follows. A brief review of domestic U.S. production and supply balances of the three primary fertilizer nutrients used in agriculture: nitrogen, phosphate, and potash. This is followed by nutrient and cropland demands from U.S. produced corn starch-derived ethanol since the implementation of the RFS in 2006. A discussion of the findings and resulting conclusions completes the paper.

4.2 U.S. Nutrient Production and Supply

In terms of a substitute for oil, U.S. biofuel production is coming almost entirely from agricultural crops and products. Extensive agricultural gains over the last century have made it possible for U.S. farmers to supply both their historical consumer base and now energy sector demands as well. While advances in seed genetics and technology deserve credit, a large portion of these gains can be attributed to the increasing quantities of non-renewable fertilizer nutrients applied. During the last half-century, American agriculture's use of the three primary fertilizer nutrients--nitrogen, phosphate, and potash--has almost tripled in consumption (USDA ERS[b], 2013).

Both phosphate and potash are derived from geological ore deposits, while nitrogen is produced through a chemical process using primarily natural gas.[38] All three are non-renewable resources with a limited domestic supply. Current domestic reserves of phosphate rock and potash stand at 1,100,000 and 200,000[39] thousand metric tons respectively (USGS[c], 2015). In terms of global phosphate rock and potash reserves, this equates to less than 6% and 2%, respectively. The global reserve balance of both nutrients is highly skewed, with Morocco and Western Sahara controlling nearly 75% of known phosphate reserves and 70% of global potash reserves being controlled by three countries (Canada, Belarus, and Russia). At present, the U.S. has a reserve base of 354 trillion cubic feet of natural gas, representing approximately 5% of global natural gas

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[38] This is known as the Haber-Bosch process.

[39] This figure reflects K_2O content equivalent to 1,700,000 thousand metric tons of recoverable ore.

reserves (US EIA, 2015). The term ‘reserves’ indicates in-situ stock that is currently economically extractable. Thus, reserves are dynamic in nature, changing under various fluctuations in market conditions.

While the U.S. domestically manufactures all three primary nutrients, it is an overall net importer with only phosphorous having a positive trade balance. Domestic production of these three primary nutrients, since the implementation of the RFS in 2006, can be seen in Table 4.2. During this time period production levels have remained relatively stable. What is not seen in Table 4.2 however is the low number of domestic producers involved in the production of each nutrient type. Currently, there are only two domestic producers of potash, five domestic producers of phosphate, and 13 domestic producers of nitrogen (IFDC, 2014). Thus a stable domestic supply of these highly valuable agricultural inputs are reliant upon only a handful of producers. With such a low number of producers, plant shutdowns or short-term idling of plants could have a significant impact on domestic nutrient production capabilities, which would in turn impact domestic biofuel production.

[Insert Table 4.2]

To determine a crude measurement for the lifespan of domestic production remaining, a ratio of current domestic nutrient reserves to annual domestic nutrient production may be taken. Using this static measure, Barrowclough and Geyer (2015) show that the U.S. reserve supply of nitrogen, phosphate, and potash will be depleted in 14, 39, and 221 years respectively.[40] While this static ratio ignores changes in price over

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[40] The terms “Reserve” and “Reserve Base” is used following the definition set forth by the U.S. Department of the Interior. In Barrowclough and Geyer (2015), the following assumptions were made: 1) Extraction rates remain constant at the 2013 levels; 2) No additional domestic discoveries are made; and 3) All nitrogen production comes from natural gas. Under these same assumptions, the reserve base (which

time, potential for new discoveries, and the conversion of non-economically feasible reserves to economically feasible ones, it does provide a glimpse of the limited nature of domestic nutrient resources available.

The recent trend of fertilizer prices has been one of rapid increases, with prices more than doubling over the last decade (USDA ERS^{a}, 2015). If this upward price trend continues it is likely to cause nutrient reserve stocks to rise, thus expanding the life span of domestic supply.[41] Notwithstanding the limited nature of these nonrenewable nutrients, the effect of any price increases will not go on indefinitely, as the nutrient quality of both phosphate rock and potash tend to decline as mining deepens. This reduction in nutrient quality causes the marginal cost of extraction of the converted reserve stock to increase, thus limiting feasible reserves.

4.3 Corn Based Ethanol Nutrient and Cropland Demand

Traditionally, domestic conventional biofuel (ethanol) has been produced from cornstarch. Two underlying reasons are its abundant supply as a feedstock and its high starch content, which is necessary for converting to ethanol. In terms of both yield and acreage planted, corn is the leading crop produced in the U.S., with 14.2 billion bushels produced on 83.1 million acres in 2014 alone (USDA NASS, 2015). Over the last decade corn has consumed nearly half of all domestic nutrients used in agriculture and used the most cropland of any crop, demanding on average 20% of U.S. cropland (USDA NASS, 2012). With a single crop utilizing such significant amounts of two key agricultural

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includes economic and subeconomic reserves) supply of nitrogen, phosphate, and potash will be depleted in 95, 120, and 330 years respectively.

[41] Two likely causes for this occurrence will be: 1) a reduction in the amount of nutrients consumed due to increase in cost; and 2) reserves that were once economically infeasible will become feasible due to the increase in price.

inputs, a more thorough analysis of corn ethanol's impact on these key inputs is warranted.

The U.S. has produced between 10.5 and 14.2 billion bushels of corn since 2006. This production has required significant amounts of fertilizer nutrients, particularly the three primary nutrients of nitrogen, phosphate, and potash (see Table 4.3). In comparing the annual nutrient demands of corn to the domestic production of nutrients seen in Table 4.2, it is easily seen just how large a consumer corn is of these three primary nutrients. For example, corn consistently consumed between 50% and 60% of all domestically produced nitrogen. In addition, corn applied almost double the amount of potash every year than the U.S. produced and 20% of domestic phosphate production. These estimates highlight the significance that domestic nutrient reserves and production capabilities have on not only biofuel production, but also the sustainability of an independent and self-sufficient agricultural sector in general.

[Insert Table 4.3]

Because not all corn is used to produce ethanol, the demands placed by corn starch-derived ethanol needs to be examined separately. Multiplying together the share (%) of corn production used as an ethanol feedstock and the amount of nutrients used for the entire corn crop, the nutrient demands of corn starch-derived ethanol were found:

$$CEND_{it} = CPEF_t \times F_{it}, \tag{11}$$

where *CEND* = corn ethanol's nutrient demand, *CPEF* = corn production used as ethanol feedstock (%), *F* = fertilizer nutrient amount used in corn production, *i* = nitrogen, phosphate, or potash, and *t* = 2006, 2007, …, 2014. Table 4.4 shows the domestic nutrient demands of corn starch-derived ethanol since the RFS began in 2006. Beginning in 2006, the first year of the RFS, the share of the domestic corn harvest going to ethanol production totaled just over 20%. Increasing each year in conjunction with the RFS mandate, the portion of the corn crop expended as a biofuel feedstock peaked in 2012 at 43.2%. Since 2012, the share of the corn harvest dedicated to ethanol has remained at just over 35%.

[Insert Table 4.4]

Equation (11) provides an average quantity of nutrients demanded by corn starch-derived ethanol production. Taking the average assumes that all corn production received equal amounts of fertilizer which is obviously not the case. More than 90% of ethanol production comes from states located in the Midwest, where fertilizer rates are typically higher than the national average (IFDC, 2014). Thus, the nutrient demand estimates shown can be seen as a lower bound.

A byproduct of corn starch-derived ethanol is a product known as “Dried Distiller’s Grains (DDGs)”. Approximately one-third of every bushel of corn used in ethanol production returns to the market in the form of DDGs. This byproduct is typically used as a less expensive feed alternative in livestock production. Accounting for this byproduct has been the cause of debate, as to whether it should be considered when determining the demands placed by biofuel ethanol production. Because of this controversy, demands with and without the inclusion of DDGs are provided.

Determining the individual nutrient share (%) that corn starch-derived ethanol had on domestic nutrient production is done by dividing equation (11) by the total domestic nutrient production:

$$SDNP_{it} = \theta_j \times CEND_{it}/TDNP_{it} \tag{12}$$

where *SDNP* = share of domestic nutrient production, δ is an indicator for the inclusion of DDGs equaling 2/3 when j =1 (DDGs included) and 1 when j =0 (DDGs excluded), and *TDNP* = total domestic nutrient production. The share of domestic nutrient production demanded by corn starch-derived ethanol is significant, with and without the inclusion of DDGs. Excluding DDGs from consideration, corn starch-derived ethanol nutrient demands from 2006-2014 ranged from 3.3%-8.8% of phosphate production to 31.5%-78.4% of potash production. Demands placed on nitrogen production ranged from 10.5%-24.8%. Including DDGs into the calculation, these ranges are simply reduced by one-third. A graphical representation of these demands can be seen in Figure 4.1. As would be expected, as the RFS mandate has increased annually the demand of nutrients has increased with it.

[Insert Figure 4.1]

Beginning in 2011, this upward trend is disrupted with a slight downtick in domestic nutrient production demands. This can be explained by a nearly 10% increase in domestic nutrient production combined with a 10% decrease in corn's nutrient use. Demand of nutrient production then increases the following year in 2012 by over 10%. A large part of this rise can be attributed to weather related growing events that led to more than a 15% decrease in yields per acre. Due to these lower yields coupled with an increase in the RFS mandate, a higher share of the corn harvest was demanded (43.2%), raising the nutrients demanded from biofuel as well. In 2013 and 2014, nutrient demands remained relatively stable.

The overall share that corn starch-derived ethanol has demanded of domestic nutrient production over the last decade can be seen in Figure 4.2. Summing equation (12) over all three primary nutrients, then dividing by the total domestic production:

$$OSDNP_{it} = \sum_{i=1}^{3} CEND_{it} \Big/ \sum_{i=1}^{3} TDNP_{it}, \tag{13}$$

where *OSDNP* = overall share of domestic nutrient production. Estimates of the overall share demanded over the last decade varied between 5.4% and 20.2%. These figures are extremely high, particularly when considering that this estimate is of a single crop being used for a single purpose (when excluding DDGs).

[Insert Figure 4.2]

In conjunction with nutrient demands, we examine briefly corn's other major input requirement: cropland (see Table 4.5). Again using a straightforward approach, the share of cropland demanded by corn starch-derived ethanol is defined as:

$$SCD_t = [(Y_t \times 2.77)^{-1} \times CSEP_t] \times [TC_j]^{-1}, \tag{14}$$

where *SCD* = share (%) of cropland demanded, *Y* = corn yield in bushels, *2.77* being the number of gallons of ethanol a bushel of corn produces, *CSEP* = amount of corn starch-derived ethanol produced, and *TC* = total U.S. cropland with *j* = 1 applied to years 2006 – 2009 and *j* = 2 applied to years 2010 – 2014. Cropland acreage data was collected from the census of agriculture, taken in 2007 (*j* = 1) and 2012 (*j* = 2).

[Insert Table 4.5]

The amount of cropland demanded by corn starch-derived ethanol ranges from 1.9%-9.9%, depending upon the year and whether DDGs are taken into consideration (Figure 4.3). In using the average annual corn yield as a basis, the amount of cropland acreage found demanded by corn starch-derived ethanol can be viewed as an upper bound. States in the Midwest, where more than 90% of ethanol is produced, produce on average higher yields than growers outside of this region. Thus, regions with a lower yield are given equal weighting to those in the Midwest, where in fact yields in the Midwest should account for 90% of the weight attached to the national per acre yield.

[Insert Figure 4.3]

This simple and direct measurement of nutrient and acreage demands placed by corn starch-derived ethanol are alarming and calls into question whether corn being used as a biofuel feedstock meets the goals set forth by U.S. biofuel policy. The findings of nutrient and crop acreage demand requirements of corn starch-derived ethanol would suggest that this fuel type is not as sustainable as many proponents claim it to be. These preliminary results indicate that a more thorough analysis of the demands placed by corn starch-derived ethanol along with other biofuel types is warranted.

4.4 Discussion and Conclusions

With U.S. energy demands projected to continue growing over the coming decades, it is critical that all fuel types, including biofuels, are considered as a means to help secure national energy independence and sustainability. Although there is no single solution to secure this independence, there are reasonable steps that can be taken that will ensure both energy and economic security for our future.

This paper examined the demands placed on domestic nutrient production and cropland from corn-based ethanol since the implementation of the RFS in 2006. Currently, corn is used as the primary feedstock in U.S. ethanol production. Using a simple and direct approach, general findings of the nutrient demand requirements of corn starch-derived ethanol conflict with the renewable and energy independence mantra that typically accompanies biofuel discussions.

Following the RFS since 2006, corn starch-derived ethanol was found to have demanded between 7.0%-24.8%, 2.2%-8.8%, and 21.0%-78.4% of domestically produced nitrogen, phosphate, and potash respectively. In addition, cropland acreage demanded over this time period ranged from 1.9%-9.9%. Demanding such large amounts of two key agricultural inputs, one of which is undoubtedly nonrenewable, raises doubts regarding the sustainability of corn starch-derived ethanol in securing energy independence.

Current biofuel policies are requiring a larger portion of biofuel to be blended into the nation's gas reserves on an annual basis. This, coupled with speculation about an increase in the fuel blend from 10% to 15%, is causing the nation's renewable energy policy to become more dependent on a finite amount of fertilizers that have limited domestic availability as well as foreign fertilizer imports. Can current biofuel production amounts be maintained if the U.S. were to experience a negative "shock" to the fertilizer input market, such as price volatility or the lack of availability? Decreasing domestic reserves along with an increasing reliance on imported sources of fertilizers leaves the U.S. vulnerable to such possibilities.

Ethanol, along with other biofuels, can assist the U.S. in reducing its dependence on foreign oil. However, relying so heavily on the current ethanol biofuel production practices leads to a different type of dependence, one that could possibly have significant consequences for future domestic agricultural capabilities. As resource economics teaches, a non-renewable resource's in situ stock is not a signal for scarcity but rather a resource is scarce if it satisfies two conditions: 1) that is has a high demand; and 2) that it’s marginal cost of extraction is small. Most would likely agree that the first condition is satisfied regarding agricultural nutrient use. The second condition however is up for debate and is left for future research.

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Tables

Table 4.1. 2006–2014 RFS Mandate (in billion gallons)

Year	2006	2007	2008	2009	2010	2011	2012	2013	2014
Cap on Corn Starch-Derived Ethanol	-	-	9.0	10.5	12.0	12.6	13.2	13.8	13.2
Total RFS Mandate	4.0	4.7	9.0	11.1	12.9	13.9	15.2	16.5	15.9

Notes: U.S. EPA (2015).

Table 4.2. 2006–2014 U.S. Domestic Nutrient Production

Year	Nitrogen[a]	Phosphate[b]	Potash[c]
2006	9,028	10,309	1,213
2007	9,414	10,272	1,213
2008	8,675	8,683	1,213
2009	8,488	7,994	794
2010	9,138	8,909	1,025
2011	10,307	9,286	1,102
2012	9,623	8,628	992
2013	10,108	8,706	1,058
2014[d]	9,348	9,098	1,076

Notes: Nutrient production measured in 1,000 short tons.

[a] USGS[b] (2015).

[b] TFI (2015).

[c] USGS[a] (2015).

[d] Based on average production levels from 2006-2013 due to the lack of available data.

Table 4.3. 2006–2014 U.S. Corn Production and Nutrient Use

Year	Corn Production (bushels)[a]	Nitrogen[b]	Phosphate[b]	Potash[b]
2006	10,531	4,690	1,696	1,901
2007	13,037	5,714	2,066	2,279
2008	12,043	5,224	1,888	1,687
2009	13,067	4,875	1,425	1,457
2010	12,425	5,610	1,933	1,991
2011[c]	12,314	5,260	1,814	1,876
2012[c]	10,755	4,594	1,585	1,639
2013[c]	13,829	5,907	2,038	2,107
2014[c]	14,215	6,072	2,095	2,166

Notes: [a] Production measure in million bushels (USDA ERS, 2015).

[b] All nutrients are measured in 1,000 short tons (USDA ERS, 2013).

[c] Due to lack of nutrient application data, years 2011-2014 for Nitrogen, Phosphate, and Potash were estimated using the average nutrient application per bushel for years 2006 - 2010.

Table 4.4. 2006-2014 Domestic Nutrient Demands of Corn Starch-Derived Ethanol

Year	Share (%) of Corn Production Used as Ethanol Feedstock[a]	Nutrient Demand of Corn Starch-Derived Ethanol (1,000 tons)[b]			|----- ----- Share (%) of Domestic Nutrient Production[c] ----- -----|					
					Excluding Dried Distillers Grains			Including Dried Distillers Grains[d]		
		Nitrogen	Phosphate	Potash	Nitrogen	Phosphate	Potash	Nitrogen	Phosphate	Potash
2006	20.1%	943	341	382	10.4%	3.3%	31.5%	7.0%	2.2%	21.0%
2007	23.3%	1,331	481	531	14.1%	4.7%	43.8%	9.4%	3.1%	29.2%
2008	30.8%	1,609	581	520	18.5%	6.7%	42.8%	12.4%	4.5%	28.6%
2009	35.1%	1,711	500	511	20.2%	6.3%	64.4%	13.4%	4.2%	42.9%
2010	40.4%	2,266	781	804	24.8%	8.8%	78.5%	16.5%	5.8%	52.3%
2011	40.6%	2,135	737	762	20.7%	7.9%	69.1%	13.8%	5.3%	46.1%
2012	43.2%	1,985	685	708	20.6%	7.9%	71.4%	13.7%	5.3%	47.6%
2013	37.1%	2,191	756	782	21.7%	8.7%	73.9%	14.5%	5.8%	49.3%
2014	36.4%	2,210	762	788	23.6%	8.4%	73.3%	15.8%	5.6%	48.9%

Notes: [a] USDA ERS (2015).
[b] USDA ERS[a] (2013).
[c] TFI (2015), USGS (2015), and USDA ERS[b] (2013).
[d] Dried Distillers Grains accounts for 33% of corn production.

Table 4.5. 2006-2014 Corn-Based Ethanol Production Cropland Demand

		Gallons	Corn-Based	Acres	|----- U.S. Cropland Demanded (%) -----|	
Year	Yield[a]	per Acre[b]	Ethanol Produced[c]	Demanded	Excluding DDGs[d]	Including DDGs[d]
2006	149.1	413.0	4,884	11,825,465	2.9	1.9
2007	150.7	417.4	6,521	15,621,444	3.8	2.5
2008	153.9	426.3	9,309	21,836,581	5.4	3.6
2009	164.7	456.2	10,938	23,975,328	5.9	3.9
2010	152.8	423.3	13,298	31,418,338	8.1	5.4
2011	147.2	407.7	13,929	34,161,140	8.8	5.9
2012	123.1	341.0	13,218	38,763,941	9.9	6.6
2013	158.1	437.9	13,312	30,397,066	7.8	5.2
2014	171.0	473.7	14,340	30,274,241	7.8	5.2

Notes: [a] Yield is in bushels per acre (USDA NASS, 2015).

[b] Assuming technology allows for 2.77 gallons of ethanol to be produced per bushel of corn (Westhoff, 2006).

[c] Measured in million gallons of ethanol per year; (RFA, 2015).

[d] Years 2006-2009 follow the 2007 Census of Agriculture (USDA NASS, 2007) with 406,424,909 acres of cropland, while years 2010-2014 follows the 2012 Census of Agriculture (USDA NASS, 2012) with 389,690,414 acres. The assignment of cropland acreage to follow either the 2007 or 2012 Census of Agriculture was a personal choice by the authors.

Figures

Figure 4.1. 2006-2014 Corn Starch-Derived Ethanol Individual Nutrient Share (%) of Domestic Production

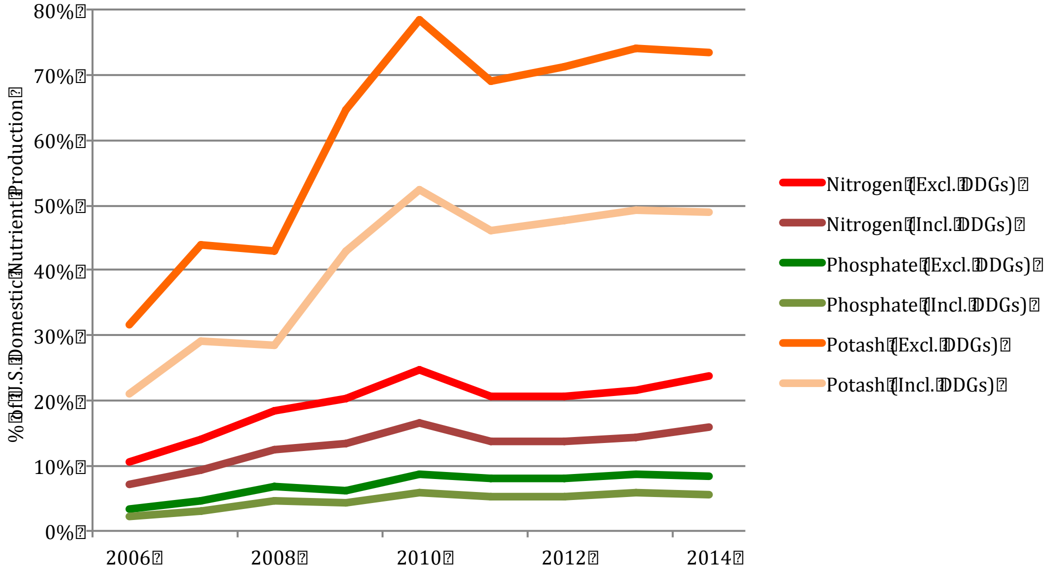


Figure 4.2. 2006-2014 Corn Starch-Derived Ethanol Overall Nutrient Share (%) of Domestic Production

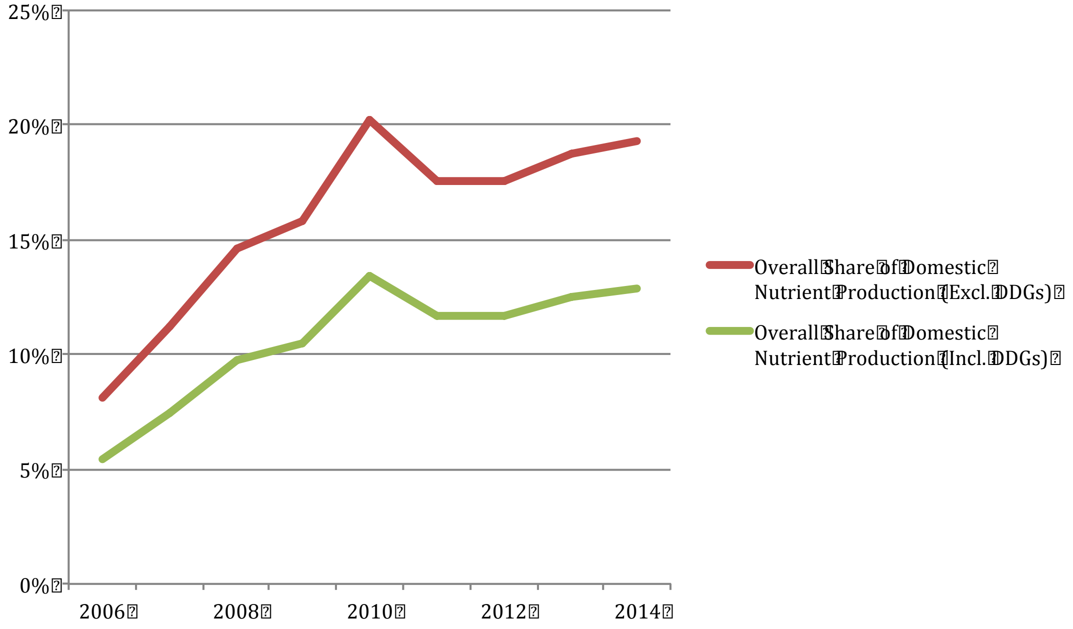
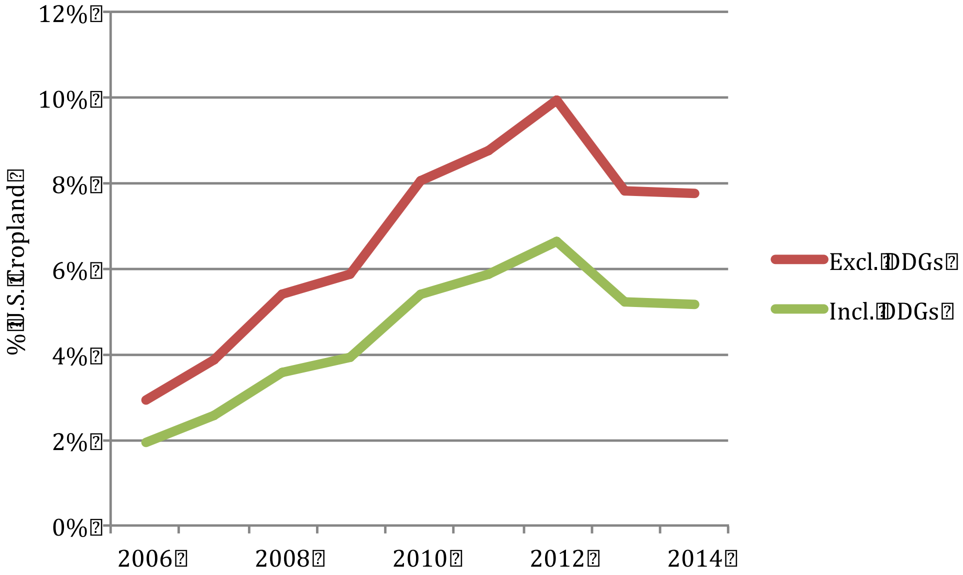


Figure 4.3. 2006-2014 Corn Starch-Derived Ethanol Demand (%) of U.S. Cropland



5 Conclusions

This dissertation focused on determining the tradeoffs associated with various agricultural decision making processes. The first two papers determined these tradeoffs associated with individual, “micro” level agricultural decisions. The last two papers determined these tradeoffs associated with national, “macro” level agricultural decisions.

The first paper investigates the tradeoffs that producers in two communities of Bolivar province, Ecuador, are willing to make when given the choice to adopt a hypothetical set of production practices referred to as “conservation agriculture”. The aim of this paper was to add to the limited literature on how poor producers view production attributes associated with these types of practices and to provide insights into their potential use in marginal, steeply sloped, small-scale production systems. Conservation agriculture is a possible solution to environmental problems associated with small-scale farming on marginal lands, yet, because little is known about producer attitudes toward these practices, research and extension agencies have been unsure about how to tailor their messages to the target audience. In this paper, nearly 25% of the study’s household population was interviewed, providing a representative sample of households in both watersheds. The study identified the key attributes related to farming in the area, conducted a choice experiment to determine the relative importance of practice attributes, and measured expected welfare changes associated with conservation agriculture adoption. Three attributes were found to be of significance to producers: crop yields, farm labor, and cost of production. For successful adoption of conservation agriculture to occur, it is critical that the practices being promoted target the constraints associated with the three attributes mentioned above. This may require outreach specialists in the study area to reconsider the set of practices currently being promoted and ensure the supported practices target these constraints.

A better understanding of the dynamic relationship between farmers and food buyers is essential in exploring the potential for more efficient marketing outcomes. The second paper uses a choice experiment approach to examine this issue from the perspective of small-scale specialty crop producers who are currently or are considering marketing their products into wholesale food markets. Producers in Virginia and North Carolina are specifically targeted. Key contract characteristics and buyer attributes are identified and producers' willingness to trade amongst these characteristics and attributes is measured. Mean willingness-to-pay for specific contract and buyer attributes, and producer-specific willingness-to-pay estimates are recovered using a mixed-logit model. Using these findings, a random-effects regression model is then used to determine factors driving producer willingness-to-pay. While expressing concerns about specific aspects of contracts, overall small farmers reported that they were receptive to the idea of using contracts as a viable marketing channel alternative. Substantial heterogeneity exists among producers in their attitudes towards the structural framework of produce contracts, suggesting that producers have competing marketing interests with varying preferences towards contract structure. Results will be of use to buyers of fruits and vegetables in helping to identify small-scale farmers who are more likely willing to market produce through contracts as well as their demands regarding contractual terms and agreements.

Considerable research has been conducted on the different aspects surrounding biofuel production. The goal of the third and fourth papers was to look at the potential effects of biofuel production on the demand of domestic nutrient production. Just like petroleum, these nutrients are non-renewable resources and once depleted will be unavailable for future needs. Both papers examined the demands placed on domestic nutrient production along with cropland from biofuel production since the implementation of the ‘Renewable Fuel Standard’ in 2006. A simple and direct approach was taken in both papers and can easily be extended to examine most any type of biofuel production coming from agriculural crop production. Results showed that since 2006, corn starch-derived ethanol was found to have demanded between 7.0%-24.8%, 2.2%-8.8%, and 21.0%-78.4% of domestically produced nitrogen, phosphate, and potash respectively. In addition, cropland acreage demanded over this time period ranged from 1.9%-9.9%. Other crops such as grain sorghum, wheat, barley, sugarcane, and sugar beets were also inspected. While grain sorghum, wheat, and barley would require a smaller volume of nutrient fertilizer application than corn, a substantial tradeoff with the amount of cropland acreage demanded would need to be made. Compared to corn’s 8% of cropland acreage demand, grain sorghum, wheat, and barley would require 21%, 29%, and 20%, respectively, of U.S. cropland acreage. Sugarcane and sugar beets require substantially less fertilizer application as well as cropland acreage than corn to reach yearly biofuel mandates, however crop production for both are restricted geographically to small portions of the country. Demanding such large amounts of two key agricultural inputs, one of which is undoubtedly nonrenewable, raises doubts regarding the sustainability of agricultural crop-derived biofuel production in securing true energy independence. The findings of nutrient and cropland acreage demand requirements of agricultural crop-derived biofuel would suggest that this fuel type is not as sustainable as many proponents claim it to be. These preliminary results indicate that a more thorough analysis of the demands placed by agricultural crop-derived biofuel is warranted.