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No. 17/07

Status, Patterns, and Microeconomic Drivers of the Extent of Diversity in Crop Production: Evidence from Afghanistan

by
Hayatullah Ahmadzai

Abstract:

We analyse the microeconomic determinants of the extent of crop diversification in Afghanistan by employing instrumental variable Tobit analysis using data from a cross-section survey of 8,613 farm households in 364 districts in all 34 provinces collected in 2013/14. The estimates of the Composite Entropy Index (CEI) show a relatively low level of crop diversification. Regression results indicate that landholding size, access to sufficient irrigation water, ownership of tractor, oxen, and cattle by the farm households, household size, landscape, and quality of land significantly increase the level of crop diversification. A significantly lower degree of crop diversification is found for farm households with higher off-farm income, and farmers living in communities with low access to all-season drivable roads. Since off-farm income is highly likely to be associated with the unobserved household characteristics such as household entrepreneurial skills and risk preferences which are omitted from the regression analysis, one would expect biased estimates of the relevant coefficients. We allow off-farm income to be endogenous and use Instrumental variable (IV) Tobit analysis revealing that endogeneity masks the true effect of off-farm income; the negative impact of off-farm income on the level of crop diversification is even greater when endogeneity is accounted for. This is consistent with the hypothesis that risk-aversion behaviour of famers generates an upward bias in the coefficient of off-farm income if endogeneity is not allowed for. Unobserved risk-aversion behaviour drive household's decision to diversify into both nonfarm income and crop mix.

JEL Classification: O12, Q12, O13, Q18, D24

Keywords: Off-farm Income, Crop Diversity, Agricultural Economics, Afghanistan

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Outline

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I. Introduction

A crucial component in the farming business is to understand the decision-making environment and behaviour of farm households, particularly subsistence smallholders that are often exposed to various types of risk and uncertainties. Understanding these decisions such as allocation of limited resources among diverse crops requires empirical evidence. Traditionally, crop diversification is regarded as a management strategy, particularly in the context of subsistence farming, where farmers choose the appropriate crop mix to sustain their livelihoods and income. Previous studies have demonstrated the economic value of crop diversification as an alternative strategy that farmers can utilize to survive and even increase incomes. Given the importance of crop diversity, this paper aims to explore farm households' decisions with regard to the magnitude of crop diversification at the micro level in Afghanistan. It analyses the status, patterns, and extent of crop diversification, and the empirical relationship between crop diversification and household socio-economic, demographic, farm, and farmer characteristics. The key focus is to examine the impact of the household off-farm income on the level of crop diversity.

Since emerging out of conflict, Afghanistan's agricultural economy has undergone drastic policy change after the establishment of the modern market-led economy in 2001. The primary emphasis of agricultural policy is to increase productivity so as to attain food self-sufficiency and increase farm incomes at national, regional, and household levels. With increased international aid[1] being pledged and greater domestic investment, Afghanistan's economy grew at a steady rate of 9.4% during 2003-2012 with a significant contribution (about 25%) from the agriculture sector (World Bank, 2014). Economic growth was perhaps accompanied by significant changes in agriculture production and consumption patterns, whilst other economic sectors such as services and manufacturing industries have been revitalized[2]. With revitalization of other sectors, and improving levels of education, farm households may be enabled to diversify into off-farm activities. This line of reasoning in turn signifies the importance of understanding the potential impact of household off-farm earnings on the extent of crop diversification.

Markets for particular commodities are imperfect and often fail to facilitate efficient trade of farm produce, forcing farmers to adjust their production decisions to compensate for losses due to such market risks. These decisions often involve the choice and degree of crop and agriculture diversification. Hence, to make informed decisions, both farmers and policy makers require empirical evidence that analyses the production environment, particularly whether adopting crop diversification under certain socio-economic conditions is an economically viable strategy.

Afghanistan's agriculture is highly dominated by the production of staple food grains. Wheat occupies the major portion of the agriculture land, followed by other grains such as maize,

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[1] International aid is an important part of the GDP growth in Afghanistan. Official development aid and military assistance grew steadily from US$404 million in 2002 to more than US$15.7 billion in 2010. About a third of this aid went into the development and civilian infrastructure including agriculture.

[2] Despite its strategic importance, agriculture setor's contribution to the GDP declined from 40% in 2002 to 25% in 2014. This is perhaps indicative of increased off-farm job opportunity in the other non agricultural sectors

barley and rice. There is evidence that the grain-based production systems may not continue to contribute as significantly in countries with a policy focus on raising incomes and production of high value market crops, generating employment opportunities, and alleviating poverty (Joshi et al., 2007). Thus, both farmers and agriculture policy makers require solid empirical understanding of the production decision-making environment, farmers socio-economic characteristics, and behaviour in order to respond to the changing market demand and consumption patterns. Adding high value horticultural crops such as vegetables and fruits to the existing production system is a well-documented production strategy that could enhance productivity while improving and sustaining farm incomes and consumption requirements (Joshi et al., 2007; Kumar and Gupta, 2015; Kurosaki, 2003; Weinberger and Lumpkin, 2007).

Heterogeneity in farmer crop portfolio in a given location and under certain socio-economic circumstances is an important empirical issue. Even in the presence of high-return alternatives both on- and off-farm, a large number of farm households still engage in producing low yield food commodities (mainly staple food grains), and crop portfolio choices vary among similar households (Stoeffler, 2016). Farmer's knowledge, technical know-how, and production management practices have significant implications on their income and costs. Without incurring additional costs, there is a high potential for many farm households to improve their productivity and income just by adding high value crops to their production agenda.

1.1. Motivation and Relevance of the Study

In many developing countries, a common problem is that farming is characterised by relatively low yields and production inefficiencies due to misallocation of resources or inefficient farm management practices. Moreover, land holdings are mostly small and expected to decline over time (due to fragmentation into smaller farms). Under these circumstances, farmers are often forced to reconsider their decisions about allocation of the scarce farming resources among different crops. With a market-led approach in mind, food grain based production system will no longer be adequate to effectively respond to the changing market demand and consumption patterns. Therefore, the challenging, and yet imperative task ahead for Afghan policy makers is to improve farm productivity, sustain farm incomes, and safeguard employment of farmers to their own land. This may require a shift from the existing food grain based system by introducing high value horticultural crops such as vegetables and fruits. This highlights the importance of understanding the status and microeconomic drivers and determinants of crop diversification.

Current studies on production efficiency find a significant and positive relationship between crop diversification and farm level technical efficiency in Afghanistan (Ahmadzai, 2017; Tavva et al., 2017). Broader research also confirms that crop diversification significantly improves farm level technical efficiency in other countries with similar economic context (Coelli and Fleming, 2004; Manjunatha et al., 2013; Ogundari, 2013; Rahman, 2009). However, Afghanistan's agriculture sector is still dominated by production of staple food crops (mainly wheat) and the country's production system remains highly undiversified. It, therefore, calls for significant transformation in agriculture system to diversify towards high value crops such as vegetables and fruits. This transformation to a diversified system that consists of high-value crops will assist farmers to improve production efficiencies, improve and sustain farm income, meet changing dietary requirements, mitigate production risks associated with mono-cropping, and improve soil quality through crop rotation.

Development theory suggests that when markets for farm produce are missing, farmers tend to produce staple food crops (mostly grains) mainly for home consumption to be self-sufficient. However, as access to markets become available farm households aim to diversify their production into high value marketable crops to earn cash income. There is a historic evidence in the agricultural economics literature that agricultural diversification in most of the South Asian countries has been demand-driven rather than an outcome of the government policy (Joshi et al., 2007). This implies that farmer's decision on the extent of crop diversification are driven by markets conditions and transaction costs.

Using nationally representative household level data, in this study we attempt to analyse the status, patterns, and extent of diversity in crop production, and to investigate empirical relationship between crop diversification and household socio-economic, demographic, farm, and farmer characteristics in Afghanistan. More precisely, the study aims to address the following specific research questions:

- What inspires farmers' decision to adopt a diversified crop portfolio? Which factors influence the extent of diversification and crop choices of smallholder Afghan farmers?
- Investigate and compare the geographical and socio-economic characteristics of farmers who adopt crop diversification with their counterparts who do not diversify
- Examine heterogeneity in crop diversification based on differences in household off-farm income

There are currently no studies that explicitly focus on empirical relationships between crop diversification and household socio-economic, farm and regional characteristics in Afghanistan and its spill over effects. Understanding this empirical relationship can improve decision-making process at the farm level and generate useful insights and implications for the Afghan policy-makers.

The remainder of this study is organized in four sections. Section II will cover the literature overview on crop diversification and estimation methods. Section III provides information on the theoretical framework for modelling crop diversification to inform empirical analysis. It also presents Idenfification strategy and econometric specification for the analysis carried out in this study. Section IV explores data, characteristics of the study area, and variables used in the analysis. We conclude with Section V by presenting empirical results and findings. Some additional information and descriptive statistics of the data will be included in the annexes attached at the end of the paper.

1.2. Scope and Limitations

The analysis in this study is based on the information generated from the household survey during a single year. Using cross-section data to analyse household production decisions makes it difficult to draw concrete policy inferences on the decision and extent of crop diversification by farm households that might be subject to change over time. However, a strength of the data is that it covers multiple seasons throughout the same year. Moreover, data are nationally representative that cover sufficient enough sample of farmers across different agro-ecological regions that represents cultural and socio-economic heterogeneity of the households and spatial variations in terms of climatic conditions.

A limitation of the data is that information is at the farm level and cannot be disaggregated by plot level or, in the case of inputs, by crop. Therefore, the analysis is limited to the estimation of aggregate measures particularly in case of area under cultivation that cannot be segregated by crops which limits the analysis at the crop or plot level. Thus, we include total land cropped by households in our analysis as a potential determinant of crop diversity.

II. Overview of Related Literature

Although crop diversification is an important part of production decision-making for a farming unit, surprisingly, it has received little empirical attention. Much of the literature on crop diversity adopts an exploratory approach to investigate cropping patterns, trends and factors that affect the decision and extent of crop diversification. There are a small number of empirical studies with econometric analysis of the determinants of producing one or multiple crops (Birthal et al., 2013; Stoeffler, 2016). In this section, we will split the previous findings of literature into two sub-sections focusing on measurement of crop diversity and empirical estimation techniques used in the crop diversity studies. We will then provide a summary of the literature assessing the empirical relationship between household non-farm income and crop intensity.

2.1. Concept and Measures of Crop Diversification

The nature of agriculture production is highly volatile and exhibits random shocks, thus crop diversification may be seen as a hedge against production or market risks. It may be regarded as the re-allocation of some of the farm's productive resources, such as land, labour, and other production inputs into different portfolios of activities (i.e. adding new crops to the existing cropping system, a combination of crop and livestock production, value-added post-harvest activities, etc.).

There are two common and complementary approaches to crop diversification in agriculture, namely horizontal and vertical diversification (Behera et al., 2007). Horizontal diversification, which is the primary approach to crop diversification in production agriculture, takes place through crop intensification by adding new crops (usually high-value crops) to existing production line or cropping systems. Vertical diversification, under which, farmers and processors add value to agriculture produce through value-added activities such as processing, branding, packaging, and other post-harvest activities to enhance the marketability of farm product. In the context of this study, crop diversification is defined as a shift in production portfolio away from mono-cropping to adopting a multiple cropping system. In developing economies, this shift in production usually occurs as farmers move away from producing staple towards high-value food commodities such as fruits and vegetables.

Depending on the objective and research question, there are several methods that are widely used in the literature to measure the extent of crop diversification. The most common method for measuring the degree of diversification is the calculation of a vector of income/revenue shares related to different income sources. While this approach puts diversification and income changes directly into the relationship, a relevant part of information related to different aspects of diversification is neglected. Other studies rely on a multidimensional perspective by employing a set of different statistical indices, which allow for a multidimensional analysis of diversification behaviour (Asfaw et al., 2016; Barrett and Reardon, 2000). Table (1) provides information on the calculation of these diversity indices, their interpretation, and usage.

Table 1: Measures of crop diversification

Method	Formula	Interpretation	Concept
Crop count	$D_i = N$	$D_i \geq 0$	Richness[i]
Margalef Index (MI)	$D_i = \frac{(N-1)}{ln(A_i)}$	$D_i \geq 0$	Richness
Herfindahl Index (HHI)	$D_i = \sum_{n=1}^{N} (P_n)^2$	$0 \leq D_i \leq 1$	Relative abundance[ii]
Simpson or Transformed Herfindahl Index (THI)	$D_i = 1 - \sum_{n=1}^{N} (P_n)^2$	$0 \leq D_i \leq 1$	Relative abundance
Berger-Parker (BP)	$D_i = 1/\max(P_n)$	$D_i \geq 0$	Inverse dominance[iii] or proportional abundance
Shannon-Weaver or the Entropy Index (EI)	$D_i = -\sum_{n=1}^{N} P_n \log(P_n)$	$D_i \geq 0$	Evenness, proportional abundance
Modified Entropy Index (MEI)	$D_i = -\sum_{n=1}^{N} [P_n \, log_N P_n]$	$0 \leq D_i \leq 1$	Evenness[iv], proportional abundance
Composite Entropy Index (CEI)	$D_i = MEI * \left[1 - \frac{1}{N}\right]$	$0 \leq D_i \leq 1$	Evenness, proportional abundance

Notes: D_i is the value of the diversity index for i^{th} household, N=Number of crops grown by the i^{th} household, A_i=Total gross revenue of all crops for the i^{th} household, P_n=revenue share of the n^{th} crop for the i^{th} household. The concepts are defined as: i) Richness is a simple count of species or crps which does not take into account their abundance or trelative distribution; ii) Relative abundance refers to how common or rare a species is relative to other species in a defined location or community; iii) Dominance is the degree to which a crop is more numerous than its competitors in an ecological community, or makes up more of the biomass; and iv) Evenness refers to how close the number of each species in an environment is; a measure of the extent to which household revenue is distributed evenly or disproportionally over the number of crops produced.

The diversity methods that measure crop or species richness are usually used in the ecological research to capture spatial biodiversity of crops and the richness of genetic resources. A limitation of measuring crop diversity at the parcel level in terms of the number of crops produced is that it masks across-parcel heterogeneity in the distribution of parcel land over the components of crop portfolio. Limiting crop diversity analysis to a subset of main crops may equivalently conceal production diversity that could represent an important contribution to household income and food security (Covarrubias, 2015). Count measures provide a general level of overall diversity on a farm, but do not account for whether the farm is growing high value cash crops or staple crops, and what percentage of resources are allocated to which crops (Turner, 2014). Bezabih and Sarr, (2012) used count measure to study linkages between risk preferences and environmental uncertainty in Ethiopia. To study on-farm diversification towards multifunctional activities in Tuscany Italy, Bartolini et al., (2014) have used a count variable to measure diversity of on-farm activities.

Given the objective of this study, the Composite Entropy Index (CEI) was selected as a primary measure for crop diversification. In addition to revenue shares of individual crops, CEI gives due weighting to the total number of crops grown by the farm household. This is important as the revenue share captures the relative importance of crops based on their economic value which may largely vary depending on the type of crops (i.e. the value of the index will be higher for households that grow larger number of high value crops). Thus, the CEI index is sensitive to the changes in the number of crops and their respective revenues. Moreover, CEI is easier to interpret as it provides a standard scale bounded by 0 and 1.

While the CEI index possesses all the desirable properties of Entropy and Modified Entropy Indices as explained in Table (1), it is adjusted by the number of crops. The detailed formula of CEI is given by:

$$D_i = -\left[\sum_{n=1}^{N} P_n \, log_N P_n\right]\left[1-\frac{1}{N}\right] = -\sum_{n=1}^{N}\frac{\ln P_n}{\ln N}\left[P_n - \frac{P_n}{N}\right]$$

Where D_i represents composite entropy index, P_n is the share of revenue from the n^{th} crop (for $n = 1, 2, \ldots, N$) grown by the i^{th} farmer, and N is the number of total crops grown by the i^{th} farm household in a given year. The computed value of the index increases with level of diversification which ranges from 0 implying no diversification (i.e. mono-cropping) to 1 implying the highest level of crop diversification.

There are a number of studies that used CEI as a measure for crop diversification: Jadhav and Deshmukh, (2014), Mandal and Bezbaruah, (2013), and Acharya et al., (2011), for Marathwada region of Maharashtra, Assam Plains, and Karnataka state of India respectively. Mesfin et al., (2011), Weiss and Briglauer, (2000), De and Chattopadhyay, (2010), Malik and Singh, (2002), McNamara and Weiss, (2005), Mishra et al., (2004), Stoeffler, (2016), and Cutforth et al., (2001) used the entropy index as a measure for crop/farm diversity in Eastern Ethiopia, Austria, West Bengal and Haryana of India, Federal State of upper Austria, USA, Burkina Faso, and Saunders county in USA respectively. Other studies have used Herfindahl and Transformed Herfindahl (or the Simson Index) indices to measure crop or income diversification. These studies include Ayieko, (2015), Babatunde and Qaim, (2009), Ibrahim et al., (2009), Rahman, (2009), and Barrett et al., (2005).

For the purpose of sensitivity of results to using different measures of crop diversification, alternative measures such as Transformed Herfindahl Index (THI) (measuring the relative abundance) was also used to test the model for robust estimates of the determinants of crop diversification. Like CEI, THI is also bounded by 0 to 1, with 0 representing the lowest level of diversification. If there is just one crop, then P_n would be 1 and the computed THI will be 0. As the number of crops increases, the share "P_n" decreases and so does the sum of the squared share, so that THI approaches 1. Assume there are N sources of revenue, then THI falls between 0 and $1-1/N$. Thus, the closer the computed *THI* is to 0, the higher the specialization, and the further it is from zero, implies the more the diversification.

2.2. Estimation Techniques and Factors Affecting Crop Diversity

Most studies on factors that influence the adoption and extent of farm diversification decisions of farm households in developing countries identify farm household socio-economic, demographic, regional, farm, farm characteristics as important (Bowman and Zilberman, 2013; Mishra et al., 2004; Ellis, 2000, 1998). The empirical relationship of these factors and diversity in crop production is analysed using various econometric techniques (Table 2).

Table 2: Previous studies on crop diversification

Study	Country	Sample	Measure of CD	Estimator
Mandal and Bezbaruah, (2013)	Assam Plains of India	342 HH's	CEI	Two-limit Tobit Analysis
Mesfin et al., (2011)	Ethiopia	167 HH's	Modified Entropy Index	Two-limit Tobit Analysis
Rao et al., (2008)	16 States of India	309 Districts	Share of land under HVC's	Modified Tobit Model
Abdalla et al., (2013)	Sudan	200 HH's	Shannon Entropy Index	Tobit Analysis
Dube et al. (2016)	Choma District, Zambia	60 HH's	Entropy Index	Tobit Analysis
Kumar et al., (2012)	Eastern India	2,885 HH's	Transformed Herfindahl Index	Heteroskedastic Tobit Analysis
Cavatassi et al., (2012)	Hararghe Ethiopia	699 HH's	Count, Shannon Index, and Berger-Parker	Poisson and Instrumental Variable Tobit
Stoeffler, (2016)	Burkina Faso	229 HH's	Count, Entropy, & Berry indices	Probit and MNL
Aneani et al., (2011)	Ghana	300 HH's	Number of crops	Multinomial Logit Analysis
Ayele et al.,(2015)	Southern Ethiopia	265 HH's	Types of crops	Multinomial Logit Analysis
Ojo et al., (2013)	Niger State, Nigeria	150 HH's	Types of crop enterprise	Multinomial Logit Analysis
Hitayezu et al., (2016)	Kwazulu-Natal, South Africa	152 HH's	Herfindahl Index	logit Transformation
Bartolini et al., (2014)	Tuscany region	72,686 HH's	Number of activity	Zero-inflated Negative Binomial
Van Dusen and Taylor, (2005)	SNP Mexico	281 HH's	Count of crops	Poisson
Acharya et al., (2011)	Karnataka India	-	CEI	OLS
Basavaraj et al., (2016)	Gadag District of Karnataka	30	Simpson and Entropy Indices	Multiple Regression
Ibrahim et al., (2009)	North Central Nigeria	100 HH's	Simpson Index	Multiple Regression
Cutforth et al., (2001)	Saunders County,Nebraska	197	Shannon index	Multiple Regression
Benin et al., (2004)	Ethiopian Highlands	739 HH's	Margalef Index	Two-stage, Probit &CLAD

The type of econometric technique depends on the type of dependent variable (i.e. different measures for crop diversification presented in Table 1). In Table (2), we summarize previous studies, the estimation techniques, and methods used to measure crop diversification. Because most of the indices used to measure crop diversification can be censored at one or both sides, Tobit analysis is one of the most common methods used in crop diversification analysis. While majority of these studies use Tobit analysis, some other studies argue that the decision to diversify crop portfolio involves selectivity bias and therefore use Hackman two-stage model. These studies include Kimhi and Chiwele, (2000), Rehima et al., (2013), Kanyua et al.,(2013), Kumara et al., (2016) Seng, (2014), Omiti et al., (2009).

Most of the studies on developing countries listed above find a significant relationship between crop diversity and standard determinants such as farm characteristics (i.e. farm size, land quality, landscape, and access to irrigation), farmer characteristics (such as age, sex, and education of the farm operator), access to infrastructure and services (such as access to roads, market, transport equipment, and extension services), and geographical characteristics capturing differences in cultural and physical conditions.

The descriptive analysis of the data for Afghanistan shows that 33% of the farmers do not diversify, whereas majority of the farmers who actually diversify grow only two or three crops. Provided that the data do not seem to exhibit that crop diversification is the outcome of two-stage decision (i.e. whether to adopt diversification and the decision on intensity of diversification), but rather a single decision process, thus in this study we did not use Heckman two-stage model. Given that our dependent variable (CEI) is censored and the fact that diversification appears to be the outcome of a single decision process, Tobit analysis seems to better fit the data.

2.3. Off-farm Income and Magnitude of Crop Diversification

Heterogeneity in the motivation and constraints faced by rural households plays a key role in households' diversification behaviour. As per the development economic literature, these motives can be driven by "pull" and "push" factors. With a fall in agriculture income and when farm income alone cannot provide sufficient livelihood, farm household may be "pushed" to diversify into non-agriculture activities to stabilize their incomes given the variability of farm income (Minot et al., 2006; Mishra and Goodwin, 1997). McNamara and Weiss, (2005) stated that if farm income falls below the household reservation wage, household members will allocate time to off-farm labour. Meanwhile, households are maybe pushed by higher returns to labour and or capital particularly in the less risky nature of investment in the off-farm sector (Ellis, 1998; Kilic et al., 2009).

On the other hand, household may be "pulled" into farming business and on-farm diversification when prevailing market conditions for agriculture commodities present opportunities that offer them a comparative advantage (Ayieko, 2015). Pull factors generate opportunities for diversification of income sources related to commercial agriculture, improved infrastructure, and better market access.

Given the literature on the constraints and motivation of on- and off-farm diversification, limited attention has been devoted to assessing a causal relationship between off-farm income and crop diversification. Weiss and Briglauer, (2000) indicated that the existence of additional off-farm income reduces the degree of diversification because part-time farms (i.e. farmers who engage in both farm production and non-farm activities) have less labour time to allocate to the production of a broad agricultural product mix. More importantly, off-farm income is considered as a strategy to diversify employment risks and thus reduces the necessity to diversify on the farm.

Similarly, Mishra et al., (2004) reported an inverse relationship between off-farm income and the level of crop diversification for US farm households. They argued that time allocation of farmer and family labour between farm and off-farm alternatives influences on-farm enterprise diversification. If the household members are working full time on the farm, this may be an indicator that the comparative advantage for their labour is on the farm. Hence, they would be more likely to diversify on-farm enterprises to increase profit. Mishra and Goodwin, (1997) pointed out that If farmers are risk averse, greater farm income variability should increase off-farm labour supply to sustain incomes. Hitayezu et al., (2016) also reported a negative relationship between off-farm income and intensity of crop diversification in the Midlands region of Kwazulu-Natal of South Africa. They argued that access to off-farm work increases the opportunity cost of on-farm diversification efforts.

On the contrary, Cavatassi et al., (2012) found that participation in non-farm activities is positively associated with the number of crops grown by households. They argue that household motivation in off-farm activities are driven by the liquidity constraints which enhance diversity by allowing households to purchase inputs. Similarly, Girish and Mehta (2003) investigated the empirical relationship between the magnitude of diversification and socio-economic factors and showed that non-farm income significantly increased level of crop diversification in Himachal Pradesh of India. Based on their explanations, because non-farm income significantly contributes to the overall income and well-being of households, it increases crop diversity through this income effect.

III. Methodology and Theoretical Framework

This section presents a theoretical framework to inform the empirical analysis. The most fundamental theoretical question that researchers in the field of agricultural economics continue to ask is, which farmers diversify and why? Motives for crop diversification by the farm households may vary depending on the objectives pursued by them. Farmers may adopt a more diversified cropping system to stabilize their income or minimize production risks caused by adverse farming conditions and shocks. As for the evidence in the broader literature on rural livelihood diversification, a number of studies have pinpointed the socio-economic rationale of farm households for pursuing a diversified crop portfolio.

In assessing diversification strategies by the rural households, Reardon et al., (2001) and Barrett et al., (2005) argued that heterogeneous constraints and incentives play a fundamental role in determining livelihood diversification patterns. Wealthy and poor farmers behave differently considering the diversification decision depending on the endowment of initial assets. Rich farmers with engagement in capital intensive activities may see diversification as a method for increasing return on agricultural capital and therefore they aim to maximise their profits, whereas poor farmers with engagement in higher labour-intensive activities may have a different incentive, that is to mitigate production and market risks. In Burkina Faso, rich farm households have more diversified crop portfolio and mostly engage in producing high-yield and high-value crops, whereas poor farmers mostly produce basic food grains (Stoeffler, 2016).

Van Dusen and Taylor, (2005) argue that diversification is driven by the output and input factor market conditions and decreasing return to scale. For a farm household, missing or incomplete markets (usually as a result of high transaction costs) implies optimal allocation of the scarce production resources between multiple crops. This rationale can be explained by Figure (1a) and (1b) below. Figure (1a) illustrates imperfect market for crop j with a Production Possibility Frontier (PPF) that characterises the technologically efficient production mixes available to a household that aims to allocate scarce resources between crops *j* and *h*. Under perfect market conditions where there is a market for both commodities and risk is absent, farmer's decision is guided by the (exogenously given) market price (shown by the *M** line with a slope of$-P_j/P_h$), and optimality with perfect markets implies a corner solution at (*Qh*, 0*), with production of one crop (*h)*. However, when there is missing market for crop *j* and risk is present (and in absence of insurance market), the household decision on allocating resources among two crops is determined by a subjectively valued shadow price (*Pj'*) which is shaped by the household's marginal utility and availability of production resources. This defines a new downward price line (*M'*) which leads to a new optimal crop diversification solution (*Qj',Qh'*) as the household shifts from using the exogenous prices (*Pj , Ph*) and producing only crop *j* to producing at the constrained level Q'_h corresponding to the point of tangency between the price line *M'* and the PPF shown by *Q'* (Hitayezu et al., 2016; Van Dusen and Taylor, 2005). In the graph in Figure (1a), the household is assumed to produce two crops, but the results can easily be extended to producing multiple crops.

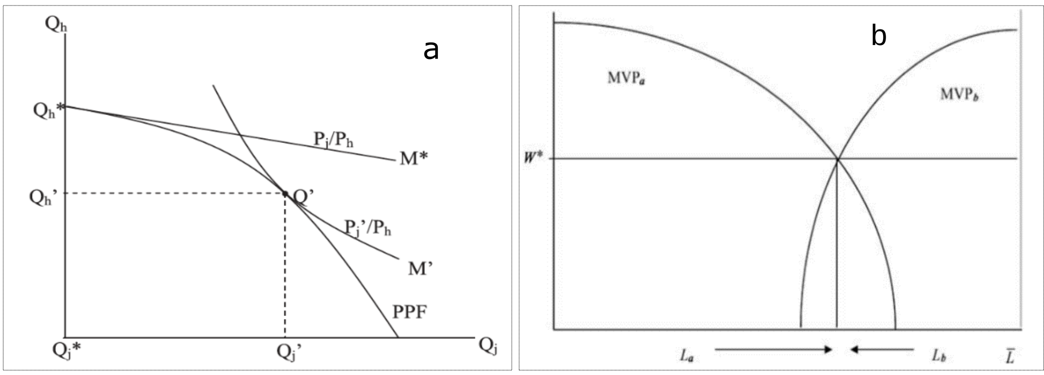


Figure 1: 1a) PPF for two crops (jand h) under perfect (*) and missing (') markets. 1b) Marginal Value Product (MVP) of crops a and b vs. a fixed factor of production

Source: Adapted from (Hitayezu et al., 2016; Van Dusen and Taylor, 2005)

Production risk may also drive the household decision towards diversification. For instance, previously it was assumed that the absence of risk and insurance market would lead the households to produce only crop *h* under perfect market condition in Figure (1a). However, assuming crop *h* is characterised by high-yield risk, then household decision on producing crop *h* will not be determined by the exogenous market price (the *M*),* but rather based on the household subjective level of risk-preferences. In this case the household's tendency to produce only one crop (*h*) may decline, and the relevant price line would resemble M' in Figure

(1a) which implies the household would be induced to produce crop *j* to spread perceived level of risk (Van Dusen and Taylor, 2005).

A missing market brings the production of a good directly into the household's utility function (via the subsistence constraint); therefore, factors affecting the utility function also affect crop allocations (Van Dusen and Taylor, 2005). Missing or incomplete markets for inputs also play a role in household's diversification decision. Incomplete markets for assets such as land, labour, credit or insurance are major causes of diversification behaviour (Barrett et al., 2001; Van Dusen and Taylor, 2005). For instance, if hired labour is unavailable and cannot be substituted by family labour, the household's decision is driven by the fixed family labour hours available to them (Van Dusen and Taylor, 2005).

McNamara and Weiss (2005) argue that with respect to on-farm diversification, economies of scale and scope of the agricultural enterprise mix are important; if the cost function exhibits economies of scope the households would produce goods jointly instead of separately. McNamara and Weiss (2005) and Van Dusen and Taylor (2005) suggested that the households rationale for diversifying crop activities may be due to Decreasing Returns to Scale (DRS) by a given set of production technology. This can be illustrated by Figure (1b) which portrays a production factor (family labour L, assuming it is fixed at $\bar{L}$) being allocated between two crop activities (L_a and L_b). A decreasing marginal value product (MVP), such as fixed endowment of land, soil quality, distance from market, or other input that results in a decreasing MVP of labour, shows DRS with respect to the family labour (depicted on the horizontal axis). For instance, if hired labour is not available or cannot be substituted for family labour , the household is left with the endowment of family labour available for crop production. In this case, if the household could only allocate labour to producing two crops, it would do so until the marginal value product of labour is equated between two activities at an endogenous 'shadow' family wage, w^*.

3.1. The Agriculture household model

Farm household decisions on crop choices and extent of diversification can also be understood in the context of the farm household model initially developed by Singh et al., (1986) which assumes farm households are both consumers and producers of agricultural goods subject to constraints. A number of studies in the recent literature focusing on on-farm diversity adopted this approach to explore the decision of farm households with regard to the intensity of farm or crop diversification (Hitayezu et al., 2016; Cavatassi et al., 2012; Benin et al., 2004; Van Dusen and Taylor, 2005; Van Dusen, 2000).

In general, there are two motives and objectives that households pursue to practice crop/farm diversification that can be conceived by the potential gains in the expected utility and minimization of the coefficient of variation or risk (McNamara and Weiss, 2005). However, an empirical comparison of these frameworks (Herath, 1980) indicates that the expected utility framework is more representative for the actual behaviour. The analytical model used for this study draws upon the household model applied to study on-farm crop diversification. In case of on-farm and crop diversification, this approach is also adopted by Van Dusen (2000), Van Dusen and Taylor (2005), Cavatassi et al., (2012), and Hitayezu et al., (2016). For the purpose of this study, the household model is based on the original model of Van Dusen and Taylor (2005)

Proceeding to the household model, consider an agricultural household that maximises utility over a set of consumption goods produced on the farm (C_f), a set of purchased non-farm commodities (X_{nf}), and leisure (*l*). The expected utility gained from various combinations and levels of consumption goods directly depends on the vector of preferences of the household, denoted by Φ^{hh}, shaped by household socio-economic, cultural, and other exogenous factors. This maximization problem can be written as:

$$\max_{C_f, C_{nf}, L, X, A} \quad U\left(C_f, C_{nf}, l \mid \Phi^{hh}\right) \tag{1}$$

Subject to the following constraints facing the household:

$$p_f\left(Q_f - C_f\right) - C\left(Q_f \middle| \Phi^f\right) + Y_{nf} \ = p_{nf} C_{nf} + w(L_f + L_{nf}) \tag{2}$$

$$Q_f = f\left(\alpha, L, X_f | A, \Phi^f\right) \tag{3}$$

$$T = (L_f + L_{nf}) + l \tag{4}$$

$$Y_{nf} = y(L_{nf} | \Phi^{nf}) \tag{5}$$

The utility is constrained by the general budget constraint (Eq.2) such that the maximum expenditures of time $w(L_f + L_{nf})$ and money $p_{nf}C_{nf}$ cannot exceed the total income of a farm household in a given decision-making period (in the case of this study a season or year). Total household income is composed of farm income $p_f\left(Q_f - C_f\right)$ net of production costs $C\left(Q_f \middle| \Phi^f\right)$, and off-farm income denoted by Y_{nf} that includes remittances, stocks carried over, and other transfers which are exogenous to the season's crop choices.

The amount of agriculture produce consumed by the household (C_f) or sold $\left(Q_f - C_f\right)$ are chosen from the crop(s) output Q_f (for crop *j=1, 2, 3,…J* that household choose) which is constrained by the given production technology embedded here in the cost function $C\left(Q_f \middle| \Phi^f\right)$ where Φ^f is a vector collecting exogenous farm characteristics. Household decisions about the number of crops and the quantity is constrained by the fixed technology constraint (Eq. 3) such that the quantity of goods produced on the farm Q_f is a function of purchased inputs (X_f), Labour (L_f), a given area of land (*A*) which is allocated to different crops (here denoted by α or the set of share of land allocated between *J* crops such that $\sum_{j=1}^{J} \alpha = 1$), and exogenous characteristics of the farm Φ^f. According to Benin et al., (2004), each set of area shares implies a level or combination of crop outputs, then the objective function in Eq.1 can be re-expressed as:

$$\max_{h} \quad V\left(C_f, C_{nf}, l \mid \Phi^{hh}\right) \tag{6}$$

Where $h = \ ((\alpha_{1,} \alpha_{2,}, \alpha_{3,} \dots \alpha_n) \geq 0, C_f, C_{nf}, X, and\ L))$. The allocation of labour is constrained by the household total labour time (Eq.4) which is denoted by *(T)* available for off-and on-farm activities (denoted by L_f and L_{nf}) and leisure (*l*).

Assuming that households maximize utility, and markets for farm goods function perfectly, then production decisions by farm households can be made separately from the consumption decisions. Thus, the level of crop diversification is driven by net returns which are determined by market wage, input and output prices (*w*, p_x, and p_f), and farm physical characteristics (Φ^f). However production and consumption decisions cannot be separated under imperfect market conditions, then the household optimal choice $h^* = (\alpha^*, L^* \, C_f^*, C_{nf}^*, X^*)$ can be expressed as a reduced form function of land holding size, exogenous income, and household, farm, and market characteristics (Benin et al., 2004) and it follows that:

$$h^* = h^*\left[\alpha^*\left(A, Y_{nf}, \Phi^{hh}, \Phi^f, \Phi^m\right)\right] \quad (7)$$

Assuming that households do not explicitly value crop diversification (i.e. it is not reflected explicitly in the utility function itself) and that it is the outcome of choices made in a constrained optimization problem rather than an explicit choice (Benin et al., 2004; Van Dusen and Taylor, 2005), then crop diversification (*D*), can be expressed as a derived demand function given by:

$$D = D\left[\alpha^*\left(A, L, Y_{nf}, \Phi^{hh}, \Phi^f, \Phi^{nf}, \Phi^m\right)\right] \quad (8)$$

Where *D* represents the composite entropy index of crop diversity at the household level. Equation (8) indicate that crop diversification is a function of the initial endowments of labour (*L*), land (*A*), exogenous non farm income (Y_{nf}), farm household characteristics (Φ^{hh}), farm characteristics (Φ^f), and market conditions (Φ^m). The unit of analysis is the farm household that decides the level of diversification given a number of objectives and constraints.

3.2. Estimation Strategy

3.2.1. Identification

The expected causal relationship between off-farm income and extent of crop diversity can be either positive or negative. In the context of subsistence small scale farming system, farming often fails to provide sufficient livelihood for the households. While farming may still remain their primary source of income, households often seek alternative means of income by participating in off-farm activities. This results in the reallocation of production resources among on- and off-farm activities. Based on this argument, the off-farm income may lead to a lower level of crop diversification due to negative labour effects. On the contrary, off-farm income may have a positive impact on the level of crop diversity due to income effects. Because increased off-farm income will increase household’s capability to purchase sufficient production inputs necessary for different crops and may ease cash constraints. Thus, it will motivate the intensity of crop diversification.

The sample data suggest that as CD increases, the share of off-farm in total income falls whereas the share of farm income increases to about 50% for three or more crops (Figure 2). However, the descriptive information cannot imply any negative or positive casual correlation between off-farm income and the number of crops grown by a household. The causal impact of off-farm income on the intensity of crop diversity is hypothesized to be mixed (i.e. negative or positive). Thus these ambiguous implications of off-farm income signify the importance of assessing the empirical relationship between off-farm income and level of crop diversity.

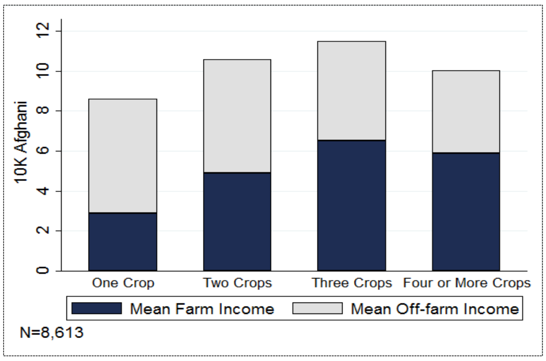


Figure 2: On- and off-farm income against number of crops
Source: Author's calculations of the ALCS 2013-14 data

Meanwhile, there might be a third category of unobserved factors affecting both on-farm diversity (i.e. crop diversification) as well as diversification towards off-farm activities. Subsistence farmers are typically assumed to be risk-averse, that may encourage farmers to diversify into both crop diversification and off-farm activities. Given that earning additional off-farm income might also be used as a diversification strategy by households to spread risk outside the farming sector, one would expect the parameter estimate of off-farm income to be biased upwards if endogeneity is not allowed for. Another example of these unobserved factors could be the entrepreneurial ability and relative efficiency that can influence both farmers' decisions about the extent of diversification and diversification towards off-farm income. Relative efficiency generates a downward bias in the coefficient on OFY if endogeneity not allowed for. Another source of endogeneity may be the presence of measurement error attributed to the recall of the extent of non-farm income earned by the household (Zereyesus et al., 2017). In the presense of measurement errors, one would expect the coefficient of off-farm income to be biased towards zero. Hence, we allow the off-farm income variable to be endogenous and use instrumental variables to identify its true effect on the intensity of crop diversity.

The cross-section household level data used in this study do not control for unobserved household fixed effects, so instrumental variable (IV) techniques are employed to control for the potential endogeneity bias in off-farm income. The estimation of the endogenous Tobit model requires the use of an IV to be included in the reduced-form equation but excluded from the structural model of crop diversification. It is therefore required that the IVs should be significantly correlated with the endogenous variable (off-farm income) but should not directly effect the level of crop diversification.

Two instruments are used to control for the endogeneity bias in off-farm income. Firstly, the share of aggregate off-farm income in the total income for all households in a given district. According to Diiro and Sam, (2015), this instrument captures the status of local non-farm labour market, thus a high share of non-farm income signifies high prevalence of non-farm employment opportunity at the local district level which in turn translates into greater potential for households to diversity into off-farm activities.

Kilic et al., (2009) use the share of non-farm employment within a district as an instrument for off-farm income, noting that, because the instrument is constructed at the district level as opposed to the village level, when regional fixed effects are controlled for it is unlikely for the instrument to have a direct effect on the agriculture decisions of households. Diiro and Sam,

(2015) argue that, controlling for family labour, the only pathway for the instrument to influence household decisions is through the household non-farm income activities. Smale et al., (2016) studied the relationship between off-farm work and farm output and used share of total non-farm earnings (business and salary) in total income by location as an instrument for off-farm income. In assessing the impact of off-farm income on farmer's liquidity constraints, Gebregziabher et al., (2012) used unemployment rate at the district level to control for potential endogeneity in off-farm income. Similarly, in examining the relationship between participation in non-agricultural labour activities and farming production decisions, Stampini and Davis, (2009) used a dummy variable for the existence of off-farm employment opportunities in the commune.

Controlling for the household's family labour and regional fixed effects by including household size and agro-ecological dummies in the analysis, we expect the existence of non-farm employment opportunity will affect household decisions to diversity only through the off-farm income channel. It is important to note that data in the sample comes from 349 districts and 34 provinces and on average there are about 50 farm households in each district.

Secondly, we use district level lagged values of off-farm income from year 2011/12 to instrument for off-farm income. Lagged off-farm income values come from the National Risk and Vulnerability Assessment (NRVA) survey conducted by the CSO in 2011/12. Off-farm income from the past is expected to positively affect farmer's current non-farm activities. Diiro and Sam, (2015) uses off-farm income from previous years as an instrument to control for endogeneity in off-farm income. According to them, income from previous years represents an important form of financial endowment that assists farm households to invest in productive farm assets. One might argue the generation of income is a dynamic process and that transitory values of past income will influence current farming decisions. However, we use district level aggregate lagged income as instrument to capture the overall non-farm employment status. There is also evidence that farmers, particularly small holders do not leave cash money on the table to transfer them from one season to another (Duflo et al., 2008).

3.2.2. Econometric Specification

Because not every farm household diversify or choose to diversify, a censoring issue underlies the empirical model. Although theoretically the dependent variable (CEI) is censored on both sides because it is bounded by 0 and 1, practically there are no computed values for CEI that are 1. Since the dependent variable is censored at 0 for 33% of the sample (i.e. non-diversifiers), the Tobit model was employed to deal with the censorship at zero of the dependent variable (CEI).[3] Conventional regression methods (i.e. OLS) fail to account for the qualitative difference between zero observations and continuous observations. Zero values of the CEI/THI indices may occur for various reasons. Even though farmer's may be potential diversifiers, they may not be able to diversify due to constraints such as soil type, climate or farm size. Households may choose to remain non-diversifiers if production of certain crops offer a comparative advantage in market or production of a particular staple food crop required

[3] We also estimated a Probit model using a binary dependent variable (i.e. 0 for those who do not diversify and 1 for those who diversified) to examine the likelihood of diversifying by the households empirically. The results (reported in annex II) from the Probit model are consistent with those from the Tobit, thus our main results are unaffected.

for food security. In these cases, zero observations represent a corner solution which is an optimal choice by the farmers not to diversify. Therefore, the zero observations are important to be accounted for. Tobit model originally developed by Tobin, (1958) with left-censored values of the dependent variable (CEI) is specified as:

$$y_i^* = x_i' \beta + \varepsilon_i \quad (9)$$

Where β is a row vector that collects unknown parameters to be estimated, x_i is a column vector of the explanatory variables that effect the extent of crop diversification, $e_i \sim N(0, \sigma^2)$, and y_i^* is a latent variable that is not directly observed, but takes on the following values:

$$y_i = \begin{cases} 0 & y_i^* < 0 \\ y_1^* & 0 \leq y_i^* \leq 1 \end{cases} \quad (10)$$

Here y_i represent the observed values of the dependent variable (CEI). However, as household Off-Farm Income (OFY) is likely to be endogenous as explained above, the following endogenous Tobit model is estimated using instrumental variables:

CD $$y_{1i}^* = \beta y_{2i} + x_i' \gamma + u_i \quad (11)$$

OFY $$y_{2i} = x_{1i} \Pi_1 + x_{2i} \Pi_2 + v_i \quad (12)$$

Where β and γ are row vectors of unknown parameters to be estimated (structural parameters), x_{1i} is *a 1 x k_1* column vector of exogenous variables that affect the level of crop diversification, y_{1i}^* is a latent variable that is not directly observed, but takes the values shown in (10) depending on y_i (the observed values of the CEI). The equation for OFY denoted by y_{2i} is written in the reduced form where X_{21} *is a 1 x k_2* vector of additional instrumental variables, and Π_1 and Π_2 are matrices of reduced-form parameters, u_i and v_i are error terms that are assumed to be jointly identically and independently distributed $(u_i, v_i) \sim N(0, \sigma^2)$. The endogeneity bias due to unobserved factors as explained above will generate an association between the error term *(u)* in Eq.11 and (*v*) in Eq. 12 (the reduced form) that will mask the true effect of off-farm income on crop diversity.

In this representation y_i^* captures the unobserved difference between the latent utility gained from crop diversification and the utility gained from choosing a single crop (non-diversified system). The latent utility is assumed to be determined by a linear function of observed household demographic, socio-economic, regional and the farm characteristics plus an observable error term (u_i). The endogenous Tobit model can be estimated using the two-step estimator proposed by Newey (1987) or Maximum Likelihood Estimator (MLE) techniques.

The estimated tobit coefficients are the marginal effects of a change in x_i with respect to y^*, the unobservable latent variable, and show the effect of a change in a given independent variable *(x)* on the expected value of the *latent* variable, holding all other independent variables constant ((Greene, 2012). However, such an interpretation may not have a quantitative meaning or may not be of interest since y^* is unobserved (e.g. we only observe y* if it is above a threshold, in our case zero). We are interested in the effect of *x* on the observable *y* (or change in the censored outcome). Depending on the purpose of the study, there are three values of interest after fitting a tobit model: 1) Marginal effects of *x* on the index or latent variable $E[y_i^*|x_i']$; 2) the expected value of *y*, conditional on *y* being positive, $E[y_i|y_i > 0, x_i]$; and 3) the unconditional expected value of *y*, $E[y_i|y_i > 0, x_i]$ (Greene, 2012).

The Expected value of the latent variable (*y*)* is simply the estimated coefficient of the tobit model:

$$\frac{\partial E[y_i^*|x_i]}{\partial x_i} = x_i'\,\beta \qquad (13)$$

Expected value of the truncated subpopulation or those who actually diversify (i.e. where *y* or CEI is greater than zero) is given by:

$$\frac{\partial E[y_i|y_i > 0, x_i]}{\partial x_i} = \beta_k \left\{1 - \lambda\left[\frac{x_i'\,\beta}{\sigma} + \lambda(\alpha)\right]\right\} \qquad (14)$$

Where $\lambda(\alpha) = \frac{\phi\left(\frac{x_i\,\beta}{\sigma}\right)}{\Phi\left(\frac{x_i\,\beta}{\sigma}\right)}$ that is also referred to as the inverse mills ratio, $\phi(.)$ is Normal Probability Density Functions (PDF), and *Φ(.)* is the normal Cumulative Distribution Function (CDF).

Unconditional expected value for observations that may be censored of the observed *y* on x is given by[4]:

$$\frac{\partial E[y_i|x_i]}{\partial x_i} = \Phi\left(\frac{x_i'\,\beta}{\sigma}\right)\beta_k \qquad (15)$$

Because we intend to estimate the determinants of the extent of crop diversification for both single croppers (i.e. with the CEI value of zero) and diversifiers (i.e. with the CEI value greater than zero), our interest is therefore in the estimation of the unconditional expected value given by Eq.15 (i.e. partial effects of explanatory variable with respect to the observed *y* being censored or uncensored). For discrete variables, *E(y)* is evaluated at alternative discrete values of X_k. Marginal effects are for the entire sample. The effects on the uncensored observations will be greater.

3.3. Standard determinants of crop diversity

The intensity of crop diversification may be driven or constrained by a number of different factors. These can be grouped into household demographic and socioeconomic characteristics, access to rural infrastructure and services, and regional differences. The

[4] As per (McDonald and Moffitt, 1980), Eq.15 can be further decomposed and rewritten as:

$$\frac{\partial E[y_i|x_i]}{\partial x_i} = \beta\{\Phi_i[1 - \lambda_i(\alpha_i + \lambda_i)] + \phi_i(\alpha_i + \lambda_i)\}$$

Where $\alpha_i = x_i'\,\beta/\sigma$, $\Phi_i = \Phi_i(\alpha_i)$, and $\lambda_i = \phi_i/\Phi_i$. Taking the two parts separately, this result decomposes the slope vector into:

$$\frac{\partial E[y_i|x_i]}{\partial x_i} = Prob[y_i > 0]\frac{\partial E[y_i|y_i > 0, x_i]}{\partial x_i} + E[y_i|y_i > 0, x_i]\;\frac{\partial Prob[y_i > 0,]}{\partial x_i}$$

Thus, a change in x_i has two effects: It affects the conditional mean of y_i^* in the positive part of the distribution, and it affects the probability that the observation will fall in that part of the distribution.

direction and degree of influence of these factors depend on household choices, access to and allocation of production resources, and motives for crop diversification. This section brefiely summarizes these factors and discusses their potential expected causal relationship with our dependent variable, the crop diversity measured by the CEI index, following the literature review above.

As per Eq.8, in theoretical model under subsection 3.1., the vector Φ^{hh} comprises a set of household characteristics. In the literature on crop diversification, household head age, gender, level of education, and household size are broadly evidenced to have influence on the intensity of crop diversification. Age of household may proxy for farmers experience and capabilities to do physical labour work. Older farmers are likely to have gained more experienced with farm management techniques and production. According to Mesfin et al., (2011) older farmers may be less risk-averse and therefore age has a negative influence on the level of crop diversification. Ibrahim et al., (2009) suggested that farmers try new crops as they age and gain more experience overtime. Ownership and access to farm assets and farm land can vary by the gender of the household head. In some cases, participation of females in crop diversification may be restricted by access to particular resources, therefore it is *ex-ante* hypothesized that male farmers have better access to resources to diversify.

Household head education is included to test whether more educated farmers have a higher propensity to diversity because of their technical skills and knowledge. The level of education of the head is assumed have an ambiguous influence on a household's decision to diversify. More education is likely associated with employment outside farming, with a negative influence on crop diversity by withdrawing labour from farming. Alternatively, higher education would be associated with better management skills and productivity, allowing them to engage in the production of a variety of crops.

Household size, the number of adults living in the household, represents the pool of family labour available for farming activities (Van Dusen and Taylor, 2005) and affects farm labour supply. Larger households may be more flexible in allocation of labour time to various activities. Mesfin et al., (2011) stated that larger household size allows the household flexibility to pool resources and share risk by taking advantage of household returns to scale and labour supply when needed in peak seasons. Against this backdrop, one would expect a positive relationship between household size and the level of crop diversification.

In addition to household demographic factors above, household socioeconomic variables such as household income, ownership land, and livestock wealth are important determinants of crop diversification. Livestock ownership by the farm households, as a proxy of wealth, may have ambiguous effects on the intensity of crop diversification (Benin et al., 2004; Van Dusen, 2000). However ownership of oxen is likely to increase the level of crop diversity by ensuring the availability of power for ploughing when needed (Benin et al., 2004). In addition, cattle ownership as a proxy for availability of animal manure, is an important source of organic fertilizer that may positively affect crop intensity. Other factors such as input and output prices are also expected to affect farmer's decision on the intensity of crop diversification (Singh et al., 1986; Van Dusen and Taylor, 2005). However, Van Dusen and Taylor (2005) argued that there are insufficient price variations in cross-section data, therefore prices are unlikely to affect crop diversity decisions in the short-run .

As per Eq.8 in theoretical framework, farm characteristics (Φ^f) including land holding size, landscape characteristics, quality of soil and land, and availability and access to sufficient irrigation water are likely to affect the decision and magnitude of crop diversity. Pope and Prescott (1980) argue that the relationship between diversification and farm size is an indicator of trade-offs between risk reduction and economics of size, that is, if there are large-scale economies in an enterprise, then one might expect larger farmers to be more specialized. On the other hand, farmers (particularly farmers with small land holdings) may attempt to diversify to reduce production risks. Ayieko (2015) stated that land under cultivation by a farm household can result either in diversification or specialization, depending on the phase of the agricultural transformation process.

The variable land, measured in hectares is the total land cultivated by the household in various seasons throughout the year. This includes both irrigated and rain-fed land owned or leased by the household that was actually cultivated throughout the year. Farms are generally small in Afghanistan. While average farm size is 1.6 hectares (equivalent to 7.9 Jeribs), majority (62%) of the farmers cultivated 1 or less than 1 hectare of land (Table 3), demonstrating that availability of farm land is an important and limiting factor for production that affects land allocation decisions. Distribution of diversity indices when farm households in the sample are grouped by the size of landholding are displayed in Table (3).

Table 3: Distribution of CEI and THI by farm size (ha)

Farm Size (ha)	CEI	THI	Number of farms	% of Farms
Up to 1	0.27	0.26	5,327	62%
1 to 2	0.32	0.30	1,931	22%
2 to 3	0.35	0.34	462	5%
More than 3	0.34	0.33	893	10%
Overall	0.29	0.28		
N			8613	

Source: Author's calculations of the ALCS 2013-14 data

From Table (3), farm size and crop diversification follow an inverse u-shaped relationship. Both indices CEI and THI of diversity initially increase with the farm size, but starting to fall when farm size is beyond 3 ha. Based on distribution of CEI across farm size in Table (3), land allocation among crops is hypothesized to have positive effect on crop diversity.

The topographic features of farm land such as slope and landscape characteristics of the farm land are also controlled for in the regression analysis. According to Van Dusen and Taylor (2005), the altitude and slope (steepness or flatness) of the farm land proxies for agro-climatic niches within farms. In assessing crop diversity, Cavatassi et al., (2012) included number of plots with different slopes in their analysis to control for variability of production conditions. In this study, we included a landscape dummy variable that equals to zero if the terrain is Valleys & Hills and 1 if it is open plain.

Soil and land quality are conjectured to affect production decisions and crop diversity. Initial analysis of the data reveals that farmers own and operate two types of land, irrigated and unirrigated (which is mainly rain-fed). If land quality is heterogeneous and yields depend on land quality, the likelihood of diverse crops is low, as yields in rain-fed agriculture are substantially lower. To control for variations in land quality, a dummy variable equal to 0 if farmers have and operate a combination of both irrigated and rain fed land, and equals to 1 if farmers cultivate irrigated land alone. It is hypothesized that farmers with rain-fed land are less likely to diversify.

Acess to infrastructure and services are other important determinants of crop diversity. Distance to local market and nearest all-season roads, as proxies for transaction costs and market development, are important determinates of crop diversification (Benin et al., 2004). Turner (2014) indicated that farms lacking access to transport infrastructure do not allocate land to marketable or cash crops. It is hypothesized that the further a farm is located from the market and drivable roads, the longer the travel time to market and the higher are the transportation costs, the lower the level of crop diversification. Transaction costs are typically grouped into variable (e.g. transportation costs) and fixed (e.g. access to market information) transaction costs (Key et al., 2000; Seng, 2014). Following Heltberg and Tarp (2002), Benin et al., (2004), and Seng (2014), we use households access to television, mobile phones, and radio as a proxy for fixed transaction costs, and access to transportation equipment as a proxy for variable transaction costs. Household's possession of transport equipment and their access to radio, TV, and mobile phones are conjectured to reduce transaction costs and induce crop diversity.

Access to extension services is vital in assisting farmers in the production decision making process since it can be a reliable source of information, technical advice, trainings and improved farm management practices. Although relatively few farmers avail themselves of extension services (about 18% of the farmers in the sample have access to extension services), it is generally perceived as an important factor to control for. To an extent, extension services may depend on the country's agriculture policy, that is in some countries extension services may encourage farmers to produce certain staple crops to achieve self-sufficiency and ensure food security, whereas in other countries polices may target production for market. It is therefore difficult to *priori* predict the impact of extension services on the magnitude of crop divarication.

Afghanistan's climate is generally characterised by hot and dry summers and unequal distribution of rainfall throughout the year. Majority of the rainfall is accumulated over the spring season. While the main source of irrigation water for the irrigated land is the running water in rivers, canals, kariz[5], the irrigation water in rivers significantly decreases during the summer seasons, often leading to a water shortage. In addition, water requirement of crops increases in the summer seasons due to hot and dry weather. As in per discriptive statistics, about 45% of the farmers indicated that they did not have access to sufficient irrigation water. To account for variations in access to irrigation water, a dummy variable equal to 0 for farms with insufficient irrigation water and 1 for availability of sufficient irrigation water was included. It is hypothesized that lack of sufficient irrigation water may restrict farmers to grow "certain[6]" crops.

[5] As per the ALCS data, about 70% of irrigation water comes from rivers, Kariz, canals in spring of 2013. During the water shortages, farmers often use alternative means such as deep well pump to irrigate their crops which is more costly due to fuel costs.
[6] Irrigation needs of crop varies from crop to crop. Generally, vegetables and fruits require more irrigation than cereals like wheat and barley. Descriptive analysis show that wheat, barley and melons are the most common crops grown in rain-fed land that require comparatively less irrigation.

Hetergogeniety with respect to regional conditions may also largely effect level of crop diversity. Based on early work by Humlum (1959) revived by Dupree (1973), Afghanistan was divided into 11 geographical zones. However, recently a study by Maletta and Favre (2003) concluded that not all the 11 zones have agricultural significance (i.e. some zones were classified as deserts). Based on ecological properties of land and climate, and some supplementary criteria about accessibility and prevailing agricultural activities, Maletta and Favre (2003) adopted the 8 agro-ecological zones scheme. These zones were constructed in the form of whole districts aggregations. Thus in this study, we adapt the eight agro-ecological zoning scheme (Figure 3a) by Maletta and Favre (2003) to control for variation in crop production attributed to agro-climatic conditions.

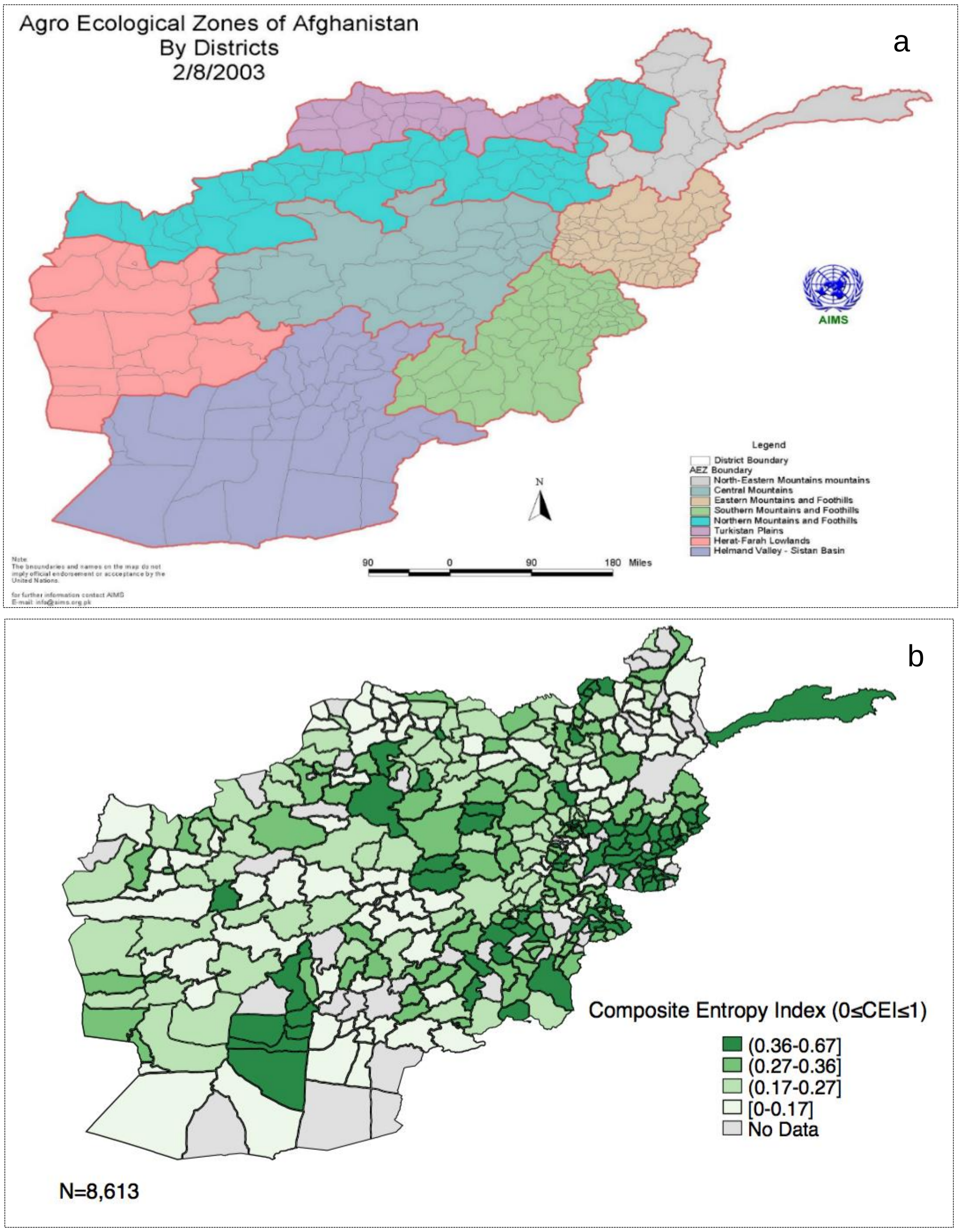


Figure 3: a) Agro-Ecological zones of Afghanistan; b) Crop diversification at district level

Source: Figure 1a) Adapted from (Maletta and Favre, 2003); 1b Author's calculations of the ALCS 2013-14 data

Since the eight agro-ecological zones are formed based on the aggregation of whole districts, we mapped the level of crop diversity by districts to illustrate the district-wise and zone-wise crop diversity (Figure 3b). Average district level CEI was first computed and classified into 4 categories. Given four levels of the CEI, the map shows the most diversified districts with green colour (CEI=0.36-0.67), and the least diversified districts with light green colour (CEI= 0-0.17).The grey areas on the map represent areas with no data. These areas are either areas with no agricultural significance (i.e. deserts and mountains) or could not be covered by the survey. In addition, these areas may represent the households that were surveyed but did not report any involvement in agriculture activities (i.e. they are non-agricultural households and did not report crop production) as discussed earlier.

Availability of irrigation water and rain or snowfall throughout the year, crop yields, farm size, market infrascture and conditions, and even cultural aspects of farmers may vary greatly by agro-ecological regions that may result in different levels of the extent of crop diversification. Heterogeneity in agro-ecology and regional differences captures these variations in physical and cultural environments. Among other unobserved climatic and cultural factors, the nature and extent of diversification is expected to differs across regions due to wide heterogeneity in farm size. As farm size varies from region to region, we expect the extent and patterns of crop diversification to greatly fluctuate.

Using different indices, Table (4) summarizes the degree of crop diversification by farm size across different agro-ecological zones. From Table (4), we note that crop diversification consistently increases with the farm size, but starting to decrease as farm size increase beyond 3 ha. Moreover, intensity of crop diversification largely varies across agro-ecological zones. Eastern Mountains and Foothills appears to be the most diversified region. This can be explained by the availability of favourable agro-ecological conditions in this region to grow different crops/varieties and the existence of relatively better market conditions. On the other and Turkistan Plains appears to be the least diversified. Turkistan plains are maybe very specialized because traditionally wheat production is very common in the area.

Table 4: Crop diversification by farm size (ha) across different agro-ecological zones using different indices

	Farm Size (ha)									
	Up to 1		1-2		2-3		More than 3		**Overall**	
Agro-ecological zone	CEI	THI	CEI	THI	CEI	THI	CEI	THI	**CEI**	**THI**
NEM	0.15	0.15	0.28	0.27	0.31	0.31	0.28	0.28	**0.20**	**0.20**
CM	0.23	0.23	0.32	0.30	0.43	0.41	0.42	0.40	**0.26**	**0.25**
HFL	0.15	0.14	0.28	0.27	0.27	0.26	0.36	0.36	**0.21**	**0.20**
SMF	0.31	0.30	0.36	0.35	0.38	0.37	0.39	0.37	**0.33**	**0.32**
HVSB	0.20	0.20	0.28	0.28	0.38	0.38	0.41	0.40	**0.27**	**0.27**
TP	0.10	0.09	0.20	0.19	0.19	0.18	0.26	0.25	**0.20**	**0.19**
NMF	0.29	0.18	0.28	0.27	0.33	0.33	0.35	0.34	**0.26**	**0.25**
EMF	0.37	0.37	0.48	0.48	0.50	0.51	0.54	0.54	**0.39**	**0.39**
Overall	**0.27**	**0.27**	**0.32**	**0.31**	**0.35**	**0.35**	**0.35**	**0.34**	**0.29**	**0.28**
N										8,613

Source: Author's calculations of the ALCS 2013-14 data

IV. Data

The data used to undertake the analysis in this study comes from the Afghanistan Living Condition Survey (ALCS) conducted by the Central Statistics Organization (CSO) in 2013/14. CSO is collecting these data about the country for more than 10 years (previously known as the National Risk and Vulnerability Assessment). The data include both quantitative survey and in-depth qualitative information on several key indicators including farming and livestock production in Afghanistan. Figure (4) shows the geographical coverage of the survey across the country where darker green represents fully covered areas. The data is disaggregated for residential populations (urban, rural and nomad). Geographically the survey covered all 34 provinces of the country. In total 35 strata were identified, 34 for the provinces of Afghanistan and one for the nomadic (Kuchi) population. The sampling frame used for the resident population in the ALCS 2013-14 was the pre-census household listing conducted by CSO in 2003-05, updated in 2009. Households were selected on the basis of a two-stage cluster design within each stratum. In the first stage Enumeration Areas (EAs) were selected as Primary Sampling Units (PSUs) with probability proportional to Enumeration Area (EA) size. Subsequently, in the second stage ten households were selected as the Ultimate Sampling Unit (USU).

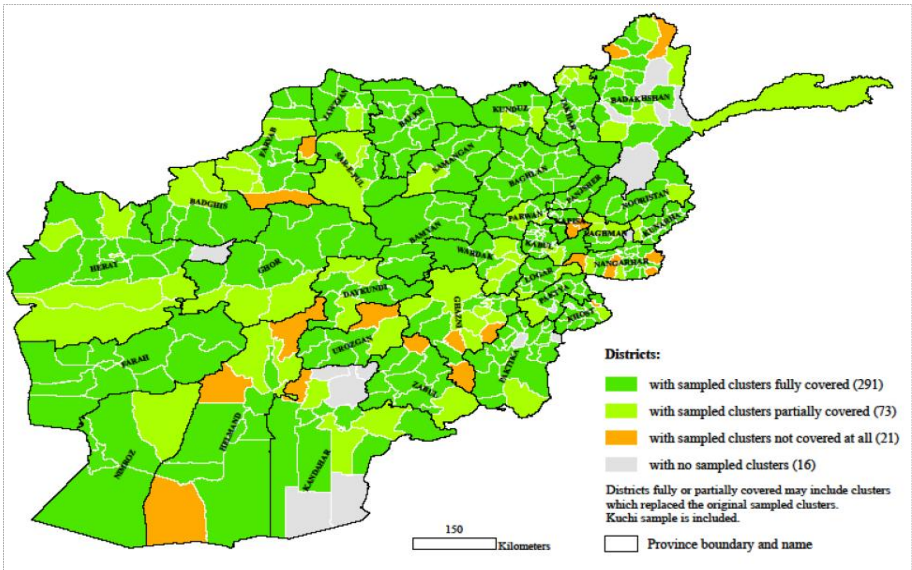


Figure 4: ALCS coverage by districts

Source: ALCS Survey Report

The reality of survey taking in Afghanistan imposed a number of deviations from the sampling design. In view of sustained levels of insecurity, clusters in inaccessible areas were replaced by clusters drawn from a reserve sampling frame that excluded insecure districts. In 182 out of 2,100 clusters (8.7 percent), originally sampled clusters could not be covered, in most cases due to security reasons. For a total of 182 clusters the coverage shifted in time or replacement clusters were selected. In addition, 19 clusters, representing 190 households, were not implemented and not replaced. Non-response within clusters was very limited. Only 845 (4.1 percent) of the households in the visited clusters were not available or refused or were unable to participate. In 841 of these non-response cases, households were replaced by reserve households listed in the cluster reserve list, leaving 4 (0.02 percent) households unaccounted for.

The data are representative at national and provincial level. It covered 20,786 households and 157,262 persons across the country. The data are unique in the sense that it also includes the nomadic (Kuchi) population of Afghanistan. Another distinguishing feature of the survey is the continuous data collection during a cycle of 12 months, which captures important seasonal variation in a range of indicators including agriculture. Using a structured questionnaire, data were collected on a number of indictors including agriculture production, labour market, household assets, education, and other household characteristics.

Initial descriptive analysis of the data showed that as many as 9,642 households reported some involvement in agriculture. However, after accounting for missing values on key variables, the total number of usable observations reduced to 8,853 households. Furthermore, the sample of agricultural households was further investigated to assess if the household who only grow a single crop on a very small amount of land (i.e. gardens) are systematically different from those who operate a relatively larger amount of land and grow major crops such as wheat, rice, cotton etc. Based on the t-test (see Table A2 in annex I), the mean difference was found to be significant between these two categories, indicating that farmers who only produce garden crops may not be regular full-time farmers but grow some vegetables while undertaking off-farm activities as their main occupation. These farmers were therefore excluded from the sample, reducing the sample employed from 8,853 to 8,613 households.

Initially the total land variable was measured in Jeribs but to avoid small parameter estimates of the land variable, it was rescaled to hectares (1 hectare is equivalent to 5 Jeribs). Similarly, off-farm income and distance to road which were originally measured in Afghani (AFN) and Km, were rescaled and measured in 10,000 AFN and 10 Km respectively.

4.1. Summary Statistics and Description of Variables

The descriptive statistics on the type of crop shows that there are a total of 22 different crops grown throughout the year (a typical agriculture year involves 1, 2, or 3 planting seasons). However, food grains such as wheat, maize, barley, and rice are the major crops. On average, wheat accounts for about 49.5% of the total value of revenue (physical output weighted by their respective prices), followed by maize (12%), rice (11.42%), potato (5.5%), and onion (5.17%). High value crops such as fruits and vegetables occupies a smaller share of the total revenues. Table (A1) and Figure (A1) in Annex I presents the frequency and total revenue of different crops grown.

Table (5) provides summary statistics for the dependent and all independent variables used in the analysis. Two different measures of crop diversification (Table 1) are used, CEI and THI indices as dependent variables, constructed based on the revenue share of individual crops that a household grow in different seasons throughout the year. Physical output of crops was weighted by their respective prices to calculate revenues (measured in Afghan currency symbolized by AFN) of individual crops. The price data used to calculate revenues comes from the NRVA 2011-12 survey that collects data on prices of different agriculture commidities at at the district-level. Lack of price data on some crops and unavailability of price data at the same year in which the ALCS survey was conducted is a limitation. However, for the purpose of this study, the price data were only used to convert physical quantities to revenues, that are used in the CEI and THI calculations.

A considerable proportion (roughly 62%) of the sample households are engaged in off-farm activities, with a sample mean of 55K AFN of off-farm earnings per household. For households who actually have access to non-farm activities, the off-farm income is highly variable and ranges from a minimum of 10K to a max of 480K AFN with a standard deviation of 130K AFN. Some farm households clearly have significant opportunities to transfer and spread risks to off-farm activities.

Table 5: Summary statistics for variables used in the analysis

Variable	Mean	SD	Min	Max
Dependent Variable				
Composite Entropy Index (0≤CEI≤1)	0.295	0.233	0.000	0.830
Transformed Herfindahl Index (0≤THI≤1)	0.283	0.232	0.000	0.830
Explanatory Variables				
Off-farm Income (in 10,000 AFN)	5.519	11.05	0.000	480.0
Total Land (Ha)	1.564	4.227	0.020	211.2
Transport Equipment (1=access, 0=otherwise)	0.450	0.498	0.000	1.000
Communication Equipment (1=access, 0=otherwise)	0.798	0.402	0.000	1.000
Cattle Ownership (N)	1.477	1.943	0.000	31.00
Oxen & Yaks (N)	0.248	0.635	0.000	9.000
Tractor & Thresher (N)	0.052	0.231	0.000	4.000
Land Quality (1=irrigated alone, 0=irrigated & rain-fed)	0.437	0.496	0.000	1.000
Landscape (1=open plain, 0=hills & valleys)	0.753	0.431	0.000	1.000
Sufficient Irrigation Water (1=access, 0=otherwise)	0.448	0.497	0.000	1.000
Household Size (persons)	8.124	3.474	1.000	36.00
Head Education: No Formal Schooling (1=yes, 0 otherwise)	0.769	0.422	0.000	1.000
Head Education: Primary & Lower sec (1=yes, 0=otherwise)	0.116	0.320	0.000	1.000
Head Education: Upper Secondary (1=yes, 0=otherwise)	0.079	0.270	0.000	1.000
Head Education: Teacher College (1=yes, 0=otherwise)	0.023	0.150	0.000	1.000
Head Education: University & Postgrad (1=yes, 0=otherwise)	0.013	0.115	0.000	1.000
Household Head Sex (0=F, 1=M)	0.995	0.067	0.000	1.000
Household Head Age (Years)	44.11	13.90	13.000	98.00
Extension Services (1=access, 0=otherwise)	0.184	0.387	0.000	1.000
Distance to Nearest Road (10 km)	2.219	3.086	0.000	20.06
Distance to Market (1=Not Reachable, 0=otherwise)	0.044	0.204	0.000	1.000
Distance to Market (1=Less than 1h, 0 Otherwise)	0.548	0.498	0.000	1.000
Distance to Market (1=More than 1h, 0 Otherwise)	0.408	0.492	0.000	1.000
Agro-Ecological Zone 1: (1=NEM, 0=0therwise)	0.023	0.151	0.000	1.000
Agro-Ecological Zone 2 (1=CM, 0=otherwise)	0.166	0.372	0.000	1.000
Agro-Ecological Zone 3: (1=HFL, 0=otherwise)	0.040	0.197	0.000	1.000
Agro-Ecological Zone 4: (1=SMF, 0=otherwise)	0.198	0.399	0.000	1.000
Agro-Ecological Zone 5: (1=HVSB, 0=otherwise)	0.105	0.306	0.000	1.000
Agro-ecological Zone 6: (1=TP, 0=otherwise)	0.068	0.252	0.000	1.000
Agro-ecological Zone 7: (1=NMF, 0=otherwise)	0.183	0.387	0.000	1.000
Agro-ecological Zone 8: (1=EMF, 0=otherwise)	0.216	0.412	0.000	1.000
Instruments				
IV1- Share of Off-farm Income in Total Income within District	0.519	0.294	0.000	1.000
IV2-Lag District Level Off-farm Income in 2011/12 (10K AFN)	507.6	568.1	11.975	9,090
N	8,613			

Source: Author's calculations of the ALCS 2013-14 data

About 23% of the household heads in the sample attended formal schooling (11.5% with primary and lower secondary, 8% with upper secondary or 12th grade, and 3% with university and graduate degree), and 99% of the households are male-headed. While the household size is large (about 8 persons per household), the average land holding size is low (1.58 ha) indicating little land per capita. Small land holdings are therefore an important constraint and allocation among different crops require careful attention. About half (54%) of the farmers in the sample live within close proximity (less than a 1 hour drive) to the permanent food market, whereas 41% have restricted access to market (located more than 1 hour drive by car), and 5% have no market access at all. Furthermore, average distance to nearest all-season drivable road is about 22 km which greatly varies across the sample. This indicates that transaction costs, particularly transport costs, are potential constraints for farmers to supply their produce to markets.

Table 6: T-test of mean difference between non-diversifiers and diversifiers

	Non-Diversifiers		Diversifiers		T-Test	
Variable	Mean	SD	Mean	SD	Difference	T-Value
Annual Revenue (AFN)	28,639	54,631	79,795	137,597	-51,155***	(-24.5)
Total Land (Ha)	1.14	2.22	1.77	4.91	-0.63***	(-8.3)
Off-farm Inc.(10K AFN)	5.72	8.58	5.42	12.07	0.30	-1.33
Farm Inc.(10K AFN)	2.9	4.63	5.34	7.98	-2.44***	(-17.8)
Own Cattle (N)	1.18	1.69	1.62	2.04	-0.44***	(-10.6)
Oxen and Yak (N)	0.2	0.53	0.27	0.68	-0.07***	(-5.1)
Tractors (N)	0.02	0.14	0.07	0.26	-0.05***	(-10.5)
Distance Road (10 km)	2.59	3.42	2.04	2.89	0.55***	-7.42

Pearson chi² test for categorical variables

		All	Specialized	Diversified	χ^2	P-val
Transport Equip.	No Access	54.95	54.77	55.04	0.056	0.813
	Access	45.05	45.23	44.96		
Communication Equip.	No Access	20.23	25.48	17.66	72.05	0.000
	Access	79.77	74.52	82.34		
Irrigation Water	No Access	55.21	62.01	51.88	78.97	0.000
	Access	44.79	37.99	48.12		
Land Quality	Irrigated only	24.66	31.24	21.44	98.12	0.000
	Combined	75.34	68.76	78.56		
Household Head Sex	Female	0.45	0.78	0.29	9.851	0.002
	Male	99.55	99.22	99.71		
Landscape	Hills & Valleys	56.29	64.45	52.29	114.2	0.000
	Open Plain	43.71	35.55	47.71		
Distance to Market	Not reachable	4.35	5.76	3.67	26.41	0.000
	Less than 1hr	54.81	52.12	56.13		
	More than 1hr	40.83	42.12	40.2		
Head Education	No School	76.86	81.1	74.79	46.77	0.000
	Primary	11.59	10.18	12.28		
	Secondary	7.92	5.8	8.96		
	T. College	2.29	1.84	2.51		
	Uni & Postgrad	1.35	1.1	1.47		
Extension Services	No Access	81.64	84.13	80.43	17.45	0.000
	Access	18.36	15.87	19.57		
Agro-ecological zone	NEM	2.33	4.28	1.38	419.6	0.000
	CM	16.6	18.98	15.44		
	HFL	4.03	6.15	2.99		
	SMF	19.84	11.52	23.91		
	HVSB	10.47	12.79	9.34		
	TP	6.79	8.87	5.78		
	NMF	18.33	21.73	16.67		
	EMF	21.6	15.69	24.49		
N		8,613	2,830	5,783		

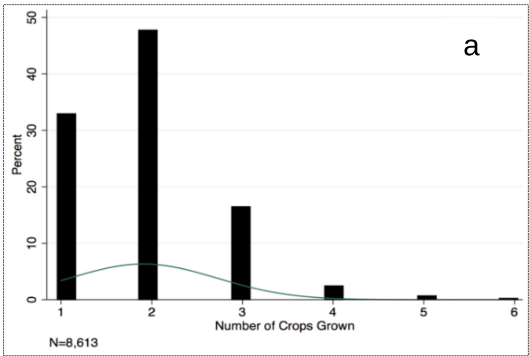
Source: Author's calculations of the ALCS 2013-14 data

Given the focus on diversification, the sample is divided into two sub-groups; diversifiers and non-diversifiers. T-test and χ^2 tests were conducted to evaluate the mean difference between diversifiers and non-diversifiers. Summary statistics and mean difference of non-diversifiers and diversifiers are presented in Table (6) above.

As evident from Table (6), the characteristics of the two-sub groups are significantly different from each other. Total annual revenue and farm income for diversifiers are significantly greater than those of non-diversifiers. Similarly, ownership of farm assets (cattle, oxen, and tractors) and use of purchased seed, fertilizer and expenditures are higher significantly higher for diversifiers (these were not retorted here). On the contrary, off-farm income and distance to the nearest road are insignificant but higher for the non-diversifiers. This is perhaps because non-diversifiers allocate a greater portion of their labour to off-farm activities which may will be their main activity.

4.1.1. Status and Patterns of Crop Diversification

The concept of crop diversification in this study implies production of multiple crops on the farm throughout the year by an individual household. The Composite Entropy and Transformed Herfindahl indices are used to measure the level of crop diversification or specialization. Descriptive statistics of number of crops grown by households show that 33% (equivalent to 2,830 out of 8,613) households grow one crop, 48% of the farmers grow two crops, 16.5% grow three crops, and about 3.5% grow four or more, with a sample average of 1.92 crops (Figure 5a). Summary statistics by number of crops are presented in Table A7 in Annex I.



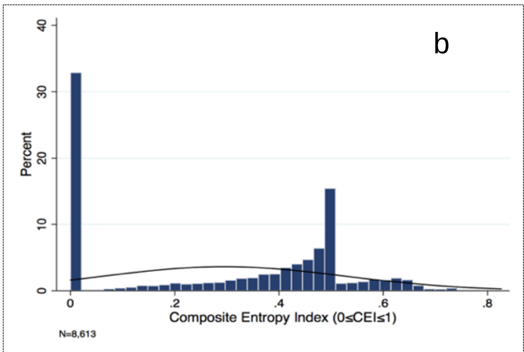


Figure 5: a) Distribution of farms wtr to the number of crops grown, b) distribution of CEI
Source: Author's calculations of the ALCS 2013-14 data

Similar statistics were generated using CEI and THI indices to measure crop diversification. Average CEI and THI for the overall sample were calculated to be 29.5% and 28.3% with standard deviation of 0.23 respectively (Table 4 of the summary statistics), whereas the CEI and THI among diversifiers is 0.44% and 42%. This suggests a low level of crop diversification relative to other comparable countries (see Table 8 in the following page).

The distribution of CEI and THI are presented in Table (7) and Figure 5b. The computed value of the CEI for 33% of the households is zero indicating that they did not diversify (i.e. growing only one crop), whereas for 52% of farms the value of CEI is between 0.1 and 0.50, and for the remaining 15% CEI falls between 0.50 and 0.82. The distribution of the THI is quite similar to the CEI (Table 7). Since THI is mainly based on the revenue shares of individual crops that households grow and CEI accounts for variation in the number of crops in addition to the share of revenue of crops, one would expect slightly higher estimates of the THI.

Table 7: Distribution of CEI and THI

	CEI		THI	
Range	No. of Farms	% of Farms	No. of Farms	% of Farms
0	2,911	33.80	3,034	35.23
0.1-<0.2	304	3.53	419	4.86
0.2-<0.3	470	5.46	552	6.41
0.3-<0.4	858	9.96	888	10.31
0.4-<0.5	2,827	32.82	2,496	28.98
0.5-<0.6	655	7.60	653	7.58
0.6-<0.7	512	5.94	481	5.58
0.7-<0.82	76	0.88	90	1.04
N	8,613		8,613	

Source: Author's calculations of the ALCS 2013-14 data

For compersion with other countries, Table (8) illustrates the relatively low level of diversification of Afghanistan's farming sector: the average value of the index for crop diversification of 0.30 in Afghanistan is comparatively lower than most other regions except Cambodia.

Table 8: Comparison of CD with other countries using different measures of CD

Study	Country of Study	Diversification Measure	Avg. Computed value
Acharya et al., (2011)	Karnataka, India	CEI	0.66
(Mandal and Bezbaruah, (2013) Benin et al. (2004)	Assam Plains India	CEI	0.39
Hitayezu et al., (2016)	Kwazulu-Natal, South Africa	THI	0.44
Kumar et al., (2012)	Eastern India	THI	0.44
(Seng, 2014)	Cambodia	THI	0.12
Mofya-Mukuka and Hichaambwa, (2016)	Zambia	THI	0.37

Note: the reported Herfindahl Index for South Africa is subtracted from 1 to produce THI.

V. Empirical Results and Discussion

Using CEI as the dependent variable based on Eq. 11 and 15, the estimated results from the Instrumental Variable Tobit (IV-Tobit, the preferred model) are reported in column 3 of Table (9), with the basic uninstrumented Tobit model in column 2 (to assess the effect of allowing for endogeneity). As the estimated raw coefficients from the Tobit model do not have an economic interpretation, unconditional marginal effects (also referred to as the unconditional expected value) are reported to show the effects of the independent variables on the overall level of diversification (i.e. for both non-diversifiers and diversifiers). For continuous variables, the marginal effects measure the change in probability of the observed *y* given a one unit change of the independent variables, holding all other variables at their mean. For discreet variables a change from 0 to 1, leaving all other variables constant at their mean.

The reduced-form model (Eq.12) for off-farm income is estimated using OLS and presented as the first stage estimates in Table (9). Conditional on other covariates, the results of the first stage demonstrate strong correlation between the two instruments and the endogenous off-farm income. Both instruments, share of the aggregate off-farm income in total income within a district and the district level lagged off-farm income from 2011/12, are positively and statistically correlated with the endogenous off-farm income at 1% level as expected. The strong correlation of instruments with the endogenous variable imply that instruments are relevant. Potential endogeneity off-farm income is investigated by applying the Wald test of exogeneity. The calculated test statistic is 142.49 and rejects the null hypothesis of no endogeneity in off-farm income at 1% significance level. This indicate that household nonfarm income is endogenous conditional on IV validity.

Test of validity of instruments was conducted using the Amemiya-Lee-Newey over-identification test estimator. The null hypothesis of over identification test is that the instruments are jointly valid, and that the excluded instruments are correctly excluded from the estimated equation. Rejections of the null hypothesis will mean that the instruments are not valid and vice-versa. As per the test statistic in Table (9), the result of Amemiya-Lee-Newey is insignificant, thus establishing the validity of the instruments.

Estimated parameters from both the uninstrumented and the preferred IVTobit models illustrate negative and significant impact of household nonfarm income on the extent of crop diversification. This implies that holding other variables at their mean, an increase of 10,000 Afghani in off-farm income (equivalent to almost 20% of mean off-farm income) decreases CD by 0.002 (a small effect corresponding to a reduction in CEI at the mean from 0.295 to 0.293). This is in line with the argument that households that engage in off-farm activity are left with limited labour to allocate to farming. The impact of non-farm income on the level of crop diversification is even greater (an increase of 10,000 in off-farm income reduces CEI by 0.015) when endogeneity is controlled for (the effect corresponds to a reduction in CEI at the mean from 0.295 to 0.28). In other words, increasing OFY by the mean value (or going from zero to 55K) would reduce mean CEI from 0.295 to 0.21.This illustrates that failing to account for the endogeneity of the household nonfarm income underestimates its negative impact on the intensity of crop diversification. This finding suggests that instrumenting for off-farm income controls for the bias due to unobserved factors, such as risk-aversion behaviour of farmers, that positively influence both nonfarm earnings and magnitude of crop diversification (Corr (off-farm income, ε) > 0 in Eq.9). The coefficient of OFY by Tobit is biased upwards (more negative) compared to IVTobit; this may be due to measurement error, or unobserved risk aversion. When we allow for endogeniety in IVTobit, effect of OFY is more negative (upward bias removed). More productive farms appear to have greater diversification and less off-farm income, and farms with OFY diversify less.

Our findings of negative impact of off-farm income are consistent with the conclusions of earlier studies that assessed the impact of non-farm income on crop diversity. Abdalla et al., (2013) found a significant reduction in the degree of crop diversification is mainly associated with the engagement in off-farm activities during the agricultural season in Sudan. Weiss and Briglauer (2000) found that the existence of additional off-farm income reduces the degree of diversification and argued that engaging in non-farm activities is used as a strategy by Upper-Austrian farmers to diversify employment risks and thus reduces the necessity to diversify on the farm.

Table 9: Unconditional marginal effects of the Tobit and IV Tobit

Dependent variable: CEI	**Tobit**		**Instrumental Variable Tobit**			
			1st stage		**2nd stage**	
Variable	ME	SE	Coefficient	SE	ME	SE
Off-farm Income (10K AFN)	-0.002***	0.000	-	-	-0.015***	0.001
Total Land (Ha)	0.004***	0.001	-0.062**	0.027	0.003***	0.001
Transport Equip. (1=access)	0.020***	0.006	0.914***	0.251	0.031***	0.007
Communication Equip. (1=access)	0.015**	0.007	0.373	0.298	0.026***	0.008
Cattle Ownership (N)	0.006***	0.001	-0.137**	0.059	0.004**	0.002
Oxen & Yaks (N)	0.037***	0.005	-0.696***	0.191	0.024***	0.005
Tractor & Thresher (N)	0.035***	0.012	0.407	0.496	0.051***	0.013
Land Quality (1=good)	0.050***	0.008	-0.279	0.340	0.050***	0.009
Landscape (1=open plain)	0.055***	0.007	0.777***	0.270	0.064***	0.007
Irrigation Water (1=access)	0.024***	0.006	0.469**	0.234	0.029***	0.006
Household Size (persons)	0.006***	0.001	0.588***	0.035	0.014***	0.001
Head Edu (1=primary &lower sec)	0.014*	0.009	1.396***	0.350	0.041***	0.010
Head Edu (2=upper sec)	0.028***	0.010	3.584***	0.419	0.088***	0.013
Head Edu (1=teacher college)	0.0001	0.018	2.107***	0.736	0.042**	0.021
Head Edu (1=uni & grad)	0.014	0.023	6.786***	0.952	0.128***	0.031
Head Sex (1=male)	0.101***	0.034	0.026	1.618	0.080**	0.040
Head Age (years)	-0.000	0.000	0.002	0.008	0.0002	0.000
Extension Services (1=access)	-0.012*	0.007	-1.107***	0.294	-0.017**	0.008
Distance Road (10 km)	-0.003***	0.001	-0.044	0.039	-0.005***	0.001
Distance to Market (1=< 1 hr)	0.007	0.014	0.372	0.559	0.030**	0.015
Distance to Market (2=> 1 hr)	0.025*	0.013	-0.317	0.549	0.016	0.015
Agro-Ecological Zone 1 (CM)	0.081***	0.016	-0.877	0.768	0.041**	0.000
Agro-Ecological Zone 2 (HFL)	-0.001	0.019	1.051	0.927	-0.023	0.023
Agro-Ecological Zone 3 (SMF)	0.141***	0.017	1.220	0.785	0.130***	0.020
Agro-Ecological Zone 4 (HVSB)	0.039**	0.018	-0.799	0.878	-0.049**	0.022
Agro-Ecological Zone 5 (TP)	-0.020	0.017	-0.517	0.867	-0.059***	0.021
Agro-Ecological Zone 6 (NMF)	0.103***	0.017	-0.700	0.773	0.065***	0.020
Agro-Ecological Zone 7 (EMF)	0.184***	0.017	-1.103	0.777	0.162***	0.020
IV1- Share of Off-farm Income in Total Income within District	-	-	10.658***	0.478	-	-
IV2-Lag District Level Off-farm Income	-	-	0.001***	0.000	-	-
Constant	-	-	-5.952***	1.876	-	-
Log-Likelihood	-3,981.40		-		-35,949.00	
Pseudo R-Square	0.121				-	-
Wald Test of exogeneity (chi2, p-value)	-	-			142.25***	0.000
Amemiya-Lee-Newey statistic (chi2, p-value)	-	-	-	-	0.500	0.479
Left censored observations(N)	2,830		-	-	2,830	
Uncensored observations (N)	5,782		-	-	5,782	
N	8,613				8,613	

*Notes: Marginal Effects for factor levels is the discrete change from the base level; significance levels indicated by * p<0.10, ** p<0.05, *** p<0.010. The omitted categories are: no access for transport equipment, no access for communication equipment, rain-fed land alone for land quality, hills and valleys for landscape, no access to sufficient irrigation water for irrigation, no formal schooling for education, no access for extension services, female for head sex, not reachable for distance to market, and agro-ecological zone 8*

Mishra et al., (2004) also found a negative relationship between off-farm income and crop diversity and pointed out that off-farm income diversifies a farm operator's income portfolio and reduces the need for on-farm enterprise diversification. Our findings are in contrast of Cavatassi et al., (2012) that found positive causal relationship between off-farm income and level of diversity in Hararghe Ethiopia and argued that the anticipated relationship between participation in non-farm activity and diversity depends largely on the motivation of the households. If participation in off-farm activities is primarily done with the intent of relaxing liquidity constraints, it may enhance diversity by allowing households to purchase inputs and seed. However, if off-farm income is regarded as an alternative to agricultural production and thus takes away labour from crop production it may lead to lower diversity.

Land holding size (i.e. total land cultivated by farm household) significantly increases crop diversity. Holding all variables at their mean, increase in land by one hectare increases crop diversity by 0.003 at the mean (alternatively an increase in land by the mean value or 1.6 ha, would increase mean CD from 0.295 to 0.30 . This small effect for a relatively large increase in land is perhaps due the fact that farm households with the largest land size are may be commercial farmers that tend to specialize. The overall positive effect of land size on crop diversity indicates that households with a relatively larger land size have the flexibility to allocate land among a variety of crops and therefore diversify.

These findings are consistent with those of Sichoongwe et al., (2014) for Zambia, Hitayezu et al., (2016) for South Africa, Kasem and Thapa (2011) for Thailand, and McNamara and Weiss (2005) for Austria. In assessing the impact of farm size on the level of crop diversity. Pope and Prescott (1980) found a positive and quadratic relationship between farm size and diversity for California crop farmers and offered the argument that there is a trade-off between scale economies and risk reduction. That is, if there are large-scale economies in an enterprise, then one might expect larger farms to be more specialized.

These claims are further supported by the descriptive analysis of the data (Figure 6). With larger farm size, farm income increases whereas off-farm income falls, indicating that farmers with larger farm sizes may allocate more labour to farming and therefore stick with farming, whereas farmers with smaller size of land are part-time farmers that may engage in off-farm activities as their main source of livelihood. On the other hand, as farm size increases, the number of crops grown initially increases, but starts to decline when land size is beyond three hectares, supporting the hypothesis that households with the largest farm size may specialize.

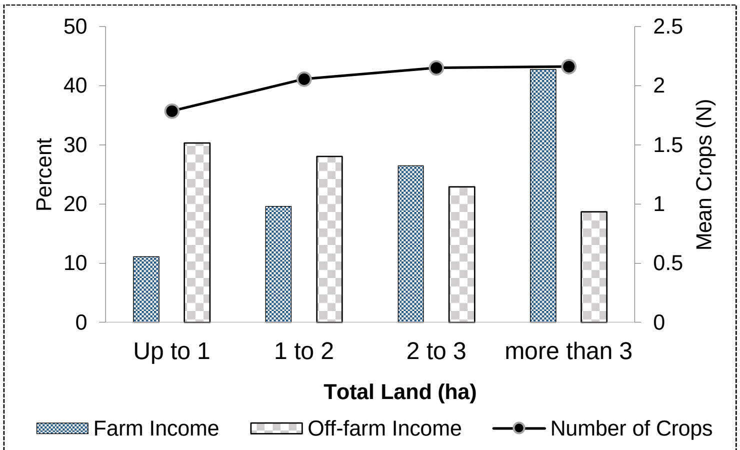


Figure 3: Farm, off-farm income, and number of crops grown against land size (ha)
Source: Author's calculations of the ALCS 2013-14 data

Farm households living in communities with poor access to all-season roads exhibit lower crop diversity, whereas households with better access to roads and permanent food markets maintain higher level of crop diversity. Improved access to roads and closer proximity to markets implies lower transaction costs due to better market infrastructure, transport and storage facilities. In addition, improved access to roads and local markets provide farming communities with better access to market information on prices for output and inputs. High-value horticultural crops such as vegetables and fruits are perishable and require sustained supply chain in order for the households to sell them in local markets. Thus, farmers located close to markets and with high road density are more likely to diversify into producing cash crops. Rao et al., (2008) finds a significant and positive impact of road density on diversification towards high value horticultural crops in India. Turner (2014) indicated that Mozambican farmers lacking access to transport infrastructure do not allocate land to marketable cash crops. Mesfin et al., (2011) finds that households that had access to information on market prices, supply, and demand are more diversified. Our findings confront with those of Sichoongwe et al., (2014) that found a positive and significant impact of distance to market on crop diversity in Zambia and indicated that farmers located further from markets may diversify for food security as their access to market is limited.

Other proxies for transaction costs such as the ownership of transport equipment by the households and their access to communication equipment such as television, mobile phone, and radio were also found to have a significant and positive influence on the extent of crop diversity. This further supports the argument that lower transaction costs enhance crop diversification. Better access to market information on input and output prices as proxy for fixed transaction costs assists farmers in production decision making. Ownership of transport equipment introduces efficiency to the cost function through availability of low-cost means of transport. Seng (2014) found that ownership of transport equipment significantly increases crop diversity in Cambodia and claimed that ownership of transport equipment reduces variable transaction costs (e.g. transport costs), providing incentive for the farmers to diversify crop portfolio, particularly increasing the production of cash crops for the purpose of selling in the market.

Households with greater number of livestock (cattle and oxen) maintain higher level of crop diversity. Cavatassi et al., (2012) pointed out that owners of oxen tend to plant greater number of crops which is perhaps due the mechanical power provided by the oxen that makes the cultivation easier. Benin et al. (2004) and Abay et al., (2009) found that oxen ownership contributes positivley to crop diversity through ensuring draught power for ploughing when needed by the households. Ownership of larger cattle herd increases the amount of manure produced at the farm that enhances soil fertility through adding organic materials to the soil and thereby positively influences the crop intensification process. Farm households that own tractors maintain higher degree of diversity. Tractor ownership by the farm households contributes to utilizing lands more efficiently and increases production efficiency through availability of cheaper and timely traction power at the time of cultivation. In addition, household may use tractors to transport their produce to the market. Our results agree with previous studies (Abay et al., 2009; Abdalla et al., 2013; Dube, 2016).

Agricultural extension services appear to have a significant negative impact on the extent of crop diversification. This is perhaps due to the policy emphasis on achieving self-sufficiency in producing staple grain food crops. While grain, particularly wheat, is the major source of nutrition, Afghanistan still imports a substantial quantity of wheat flour so there is an aim to produce more grains domestically. This is consistent with the findings of Mesfin et al., (2011) for farm households in eastern Ethiopia where number of extension visits were found to decrease crop diversity. They argued that the negative impact of extension services is associated with the extension system favouring specialization at macro level and overlooks the role of crop diversification in risk minimization. Similarly, Abay et al., (2009) found negative association between extension services and crop diversity in Northern Ethiopia and concluded that the agriculture policy incentivise production of legume and cereal crops in Tigray.

There appears to be a significant and positive relationship between land quality and crop diversification. Farmers operating on irrigated land alone are significantly more diversified than their counterparts who operate a combination of irrigated and rain-fed land. In addition, households with stable access to sufficient irrigation water throughout the year appear to be more diversified. Afghanistan in general is a dry country and the main source of irrigation is running water in canal. During the hot months of summer, irrigation water often decreases that in turn has an adverse impact on farming. As a result, farmers are restricted to grow limited number of crops, particularly since many vegetables require greater among of irrigation. Mesfin et al., (2011) confirms that irrigation intensity has a positive effect on crop diversity by enabling farmers to grow vegetables along other grains.

Farmers operating in the plains or on flat land diversify more compared to farmers with land in valleys and hills. Altitude and slope of land effects physical conditions of farming which translates into the household decisions on the number and type of crops they choose to grow. Cavatassi et al., (2012) indicated that variability in slop of the farm land leads to greater variability in diversity. Our results are in contrast of those of Van Dusen and Taylor (2005) who found that Mexican farms located in areas with steep slope are more diversified.

Except for the age of the household head, household characteristics are positively and significantly associated with crop diversification, in line with findings in the literature: household head education; household size, as a proxy for the labour supply; and households headed by a male. There is no statistically significant association between household head age and crop diversity.

We control for eight agro-ecological regions: Eastern Mountains and Foothills (EMF), Southern Mountain and Foothills (SMF), and Central Mountains (CM) were the most favourable for crop diversification compared to the reference zone (Norther Eastern Mountains–NEM). Farm households in Turkistan Plain (TP) and Helmand Valley and Sistan Basin (HVSB) zones are the least diversified. Among other heterogenous unobserved effects such as climatic, physical conditions, and cultural conditions, the level to off-farm employment/income, access to farm land, market development infrastructure and market conditions, and road density are expected to greatly vary from region to region.

In Figure (7), we plot the unconditional marginal effects off-farm income, total cropped land, and household's distance to market and roads against the expected value of CEI across agro-ecological zones to show varying effects across agro-elogical regions. In EMF and SMF regions, land size and approximity to permenant food markets have the largest positive impact on crop diversity (Figure 7b and 7c), whereas the negative impact of off-farm income and distiance to road is the least for EMF and SMF Zones (Figure 7a and 7d) . For the significantly least diversified zones such as TP and HVSB these effects follow the opposite direction.

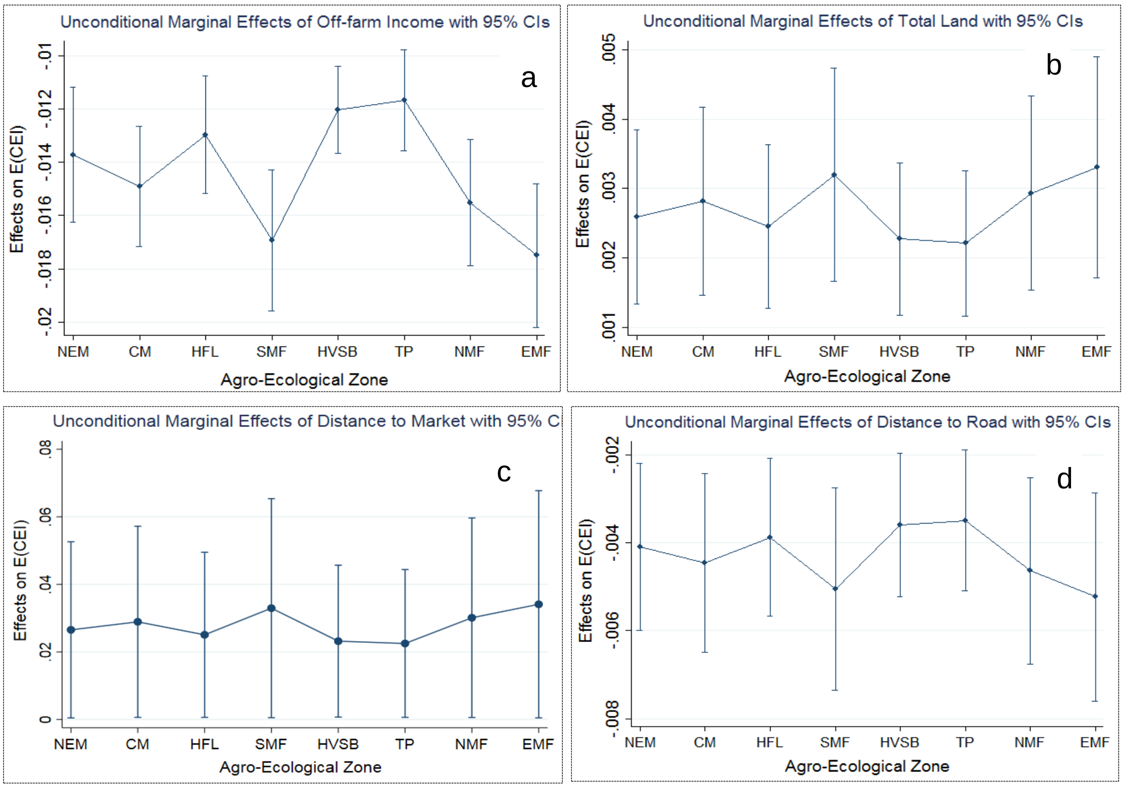


Figure 4: Unconditional marginal effects of a) off-farm income, b) cropped area, c) distance to permanent food market, and d) distance to road on the expected value of CEI across agro-ecological zones

Source: Author's calculations of the ALCS 2013-14 data

5.1. Robustness and Specification Tests

The model was checked for potential multicollinearity problem using Variance Inflation Factor (VIF) and Tolerance values. Based on the computed values for VIF and Tolerances, the calculated values for all variables except for age-squared are less than the cut-off point of 10 for VIF and greater than the cut-off of 0.1 for tolerances respectively, indicating no serious multicollinearity problem in data. As the coefficient was insignificant, age squared was dropped from the model.

For the purpose of sensitivity of results to using different measures of crop diversification, we re-estimated the IV Tobit model using an alternative measure of crop diversity, the Transformed Herfindahl Index (THI) of relative abundance as a dependent variable. The results are reported in Table A8 in Annex II and are very similar to those using CEI as the dependent variable.

Tobit model assumes homoscedastic and normality of the error term. Despite that all standard errors reported with the main results in Table (9) above are robust, we complement our analysis by reporting the results of Powell's (1984) Censored Least Absolute Deviation (CLAD) and 2SLS models. The CLAD estimator relies significantly less on distributional assumption and if heteroscedasticity is present in the data the CLAD estimator will produce consistent results. The point estimates obtained using both CLAD and linear 2SLS estimators in Table (10) are very similar to main results reported in Table 9.

Table 10: Marginal effects from CLAD and 2SLS estimators

Dependent variable: CEI	**CLAD**		**2SLS**	
	ME	SE	ME	SE
Off-farm Income (10K AFN)	-0.002***	0.000	-0.013***	0.001
Total Land (Ha)	0.014***	0.001	0.003***	0.001
Transport Equip.(1=access)	0.026***	0.006	0.027***	0.006
Communication Equip. (1=access)	0.034***	0.007	0.024***	0.007
Cattle Ownership (N)	0.004***	0.001	0.004**	0.001
Oxen & Yaks (N)	0.047***	0.004	0.023***	0.005
Tractor & Thresher (N)	-0.024**	0.012	0.044***	0.012
Land Quality (1=good)	0.081***	0.008	0.049***	0.008
Landscape (1=open plain)	0.041***	0.006	0.057***	0.007
Sufficient Irrigation Water (1=access)	0.035***	0.005	0.028***	0.006
Household Size (persons)	0.007***	0.001	0.013***	0.001
Head Edu (1=primary & lower sec)	0.015*	0.008	0.034***	0.009
Head Edu (2=upper secondary)	0.018*	0.010	0.073***	0.011
Head Edu (1=teacher college)	0.018	0.017	0.033*	0.019
Head Edu (1=uni & graduate)	0.002	0.021	0.103***	0.025
HH Head Sex (1=male)	0.077*	0.041	0.069*	0.040
HH Head Age (years)	-0.000	0.000	0.0002	0.000
Extension Services (1=access)	-0.003	0.007	-0.019***	0.007
Distance to Nearest Road (10 km)	-0.005***	0.001	-0.004***	0.001
Distance to Market (< 1 hr)	-0.017	0.012	0.026*	0.014
Distance to Market (> 1 hr)	0.007	0.012	0.011	0.014
Agro-Ecological Zone 1 (CM)	0.203***	0.022	0.021	0.019
Agro-Ecological Zone 2 (HFL)	-0.064**	0.026	-0.043*	0.023
Agro-Ecological Zone 3 (SMF)	0.276***	0.022	0.092***	0.019
Agro-Ecological Zone 4 (HVSB	0.238***	0.023	-0.066***	0.022
Agro-Ecological Zone 5 (TP)	-0.028	0.024	-0.092***	0.022
Agro-Ecological Zone 6 (NMF)	0.214***	0.022	0.046**	0.019
Agro-Ecological Zone 7 (EMF)	0.361***	0.022	0.140***	0.019
R-Square			0.559	
Pseudo R-Square	0.099			
Durbin-Wu-Hausman of exogeneity (chi2, p-value)	-	-	162.18***	0.000
Sargan-Hansen overidentification (chi2, p-value)			0.042	0.837
Cragg-Donald Wald F Statistic Weak identification (ch2, p-value)			258.06***	0.000
N	8,445		8,613	

*Notes: Marginal Effects for factor levels is the discrete change from the base level; significance levels indicated by * p<0.10, ** p<0.05, *** p<0.010. The omitted categories are: no access for transport equipment, no access for communication equipment, rain-fed land alone for land quality, hills and valleys for landscape, no access to sufficient irrigation water for irrigation, no formal schooling for education, no access for extension services, female for head sex, not reachable for distance to market, and agro-ecological zone 8*

Further to the Amemiya-Lee-Newey overidentification test presented earlier, a set of minimum distance version weak-instrument-robust tests were also carried out to examine the validity of the excluded instruments. These tests include Anderson-Rubin (AR), Conditional Likelihood Ratio (CLR), the Lagrange Multiplier (LM), overidentification (J), and a combination of the LM and J over identification (K-J) tests. These tests were carried out using the *rivtest* command in Stata 15. The confidence intervals for the off-farm income coefficient produced from the weak-instrument tests in Table (11) are not wider than the non-robust Wald confidence intervals, indicating that instruments are strong and that point estimates are robust to possible weak instrument bias. For further discussion on the weak-instrument-robust tests in limited dependent variable models see Finlay and Magnusson (2009). The test also reject that the estimated coefficient for off-farm income is zero.

Table 11: weak-instrument-robust tests

Test	H0	Test Statistic	P-value	95% Confidence Set
CLR	beta=b0	234.92	0.000	[-.024151, -.018043]
AR	beta=b0	235.35	0.000	[-.024948, -.017379]
LM	beta=b0	234.72	0.000	[-.024151, -.018043]
J	E(Zu)=0	0.630	0.4289	
LM-J	H0 rejected at 5% level			[-.024417, -.017911]
Wald	beta=b0	163.33	0.000	[-.024716, -.018143]

Note: beta is coefficient on the endogenous regressor, E(Z u)=0 indicate zero covariance is the exogeneity of the instruments where *Z* are the instruments and *u* is the disturbance in the structural equation

Source: Author's calculations of the ALCS 2013-14 data

To investigate whether crop diversity is a multidimensional decision, and to analyse whether there is disparity in the effect of explanatory variables that influence household's choices of the extent of diversification we also estimated a Multinomial Logit Model (MNL) using a dichotomous or discreet variable classifying households in terms of the number of crops they grow. For this purpose, the household were classified into four discreet categories based on the number of crops they grow; non-diversifiers and diversifiers with 2, 3, and 4 or more crops.

The MNL model used non-diversifiers (i.e. household who grow only one crop) as the base or reference category, therefore the estimated coefficient for each category of the diversification measure the change relative to non-diversifiers. Using the Maximum Likelihood estimation, the estimates of the MNL model are presented in Table A10 in Annex II. The results of the MNL model indicated that decision by household to choose a particular level of crop diversification activity is not a multidimensional or multivariate decision, and there is no significant disparity in the effect of most of the explanatory variables on the extent of crop diversity, suggesting that the analysis could be reduced single decision process that can be analysed using a Tobit model.

Thus, our results from the tobit model are maintained. The MNL model carried out in this study passes the check of the Independence of Irrelevance Alternative (IIA) assumption for different catagories of the discreet choice dependent variable. The MNL model permits the analysis of multivariate decision across more than two groups allowing the determination of choice probabilities for different categories of number of crops.

5.2. Findings and Conclusions

Using a nationally representative survey from 8,613 households, we investigated the status, patterns, and determinants of the extent of diversity in Crop Production in Afghanistan. The computed value of the composted entropy index establishes the presence of a relatively level of crop diversity in Afghanistan which greatly varies across agro-ecological regions. The results of the Tobit model revealed that household off-farm income significantly decreases the intensity of crop diversification. Using instrumental variable method, the negative impact of off-farm income is even greater when endogeneity is controlled for. This finding suggests that instrumenting for off-farm income controls for the bias due to unobserved factors, particularly risk-aversion behaviour of farmers that drive household's decision towards diversification of both non-farm activities and crop diversification.

Results from the proffered IVTobit model reveal that other factors that significantly determines the intensity of crop diversity include household characteristics (sex and level of education of the household head, and household size), farm characteristics (land size, land quality, access to sufficient irrigation water, and landscape), transaction costs (proxied for by distance to market, nearest road, ownership of transport and communication equipment), ownership of livestock units and tractors, receipt of extension services, and regional factors. Marginal analysis of the impact of land size on the expected value of crop diversity indicated that land has a quadratic impact, diminishing when land size is above three hectares.

Endogeneity of off-farm income was tested using Wald and Durbin-Wu-Hausman tests. As a result, the null hypothesis of no endogeneity of the off-farm income was strongly rejected. Weak identification tests were carried to test the validity of the instruments. Based on the estimates from the reduced form equation and various weak-instrument-robust tests, the IVs were found to be sufficiently correlated with the endogenous variable and valid. On the methodological side, since tobit model assumes homoscedasticity and normality of the error term, we report results from CLAD and 2SLS regression models which revealed no significant changes in point estimates. Therefore, our main results are maintained and IV-Tobit remains as the preferred model. We also tested the sensitivity of our estimated results to using a different measure for crop diversity. The transformed Herfindahl index was used as an alternative dependent variable that produced very similar estimates, as a result the interpretation of the main results and findings were not affected.

This research is intended to contribute to the understanding of smallholder decision-making in relation to crop portfolio diversification and factors it. It particularly has important implications for household's decisions about allocation of resources such as land and labour among on- and off-farm activities, especially since engagement of farm households on the non-farm activities reduces crop diversity. In reality, farmers are risk-averse and try to spread risk over a diverse profile of both on-and off-fam activities, particularly if farming business experiences high volatility. Policies associated with increasing opportunities for off-farm income do not contribute to crop diversification, therefore if crop diversification is the objective, policies must focus on farmers. Farmers that receive advice from extension agents appear to diversify less, thus it is may be vaiable to revisit the extension services programs if future policies aim to encourage crop diversification as a potential strategy for risk mitigation and income sustanibility.

Crop diversification as an effective farm management strategy, can help small-scale farmers to mitigate potential risks associated with mono-cropping and reallocate productive resources away from low-value food grains towards high value horticultural crops to help improve and sustain household income. Policies that incentivise farmers' access to regional and international markets through better forward and backward linkages can ease the diversification process. Investment in rural infrastructure development such as roads, storage and transportation facilities, and other means to reduce transaction costs is an equally important aspect to stabilize supply chain and thereby ensure crop diversity.

5.3. Future research

Farmers access to credit is an important area that can have implications on decision making at the fam level, particularly the level of crop diversity. Lack of access to affordable financial micro-credit can constraint crop diversification process as it my increase the need for cash to purchase extra inputs such as seeds, agro-chemicals, labour, and other equipment for the cultivation and harvest. This research could be further extended by investigating empirical relationship between farmer's access to credit and crop intensity. In addition, including more precise indicators for market development and integration in the analysis carried out in this study could further assist to derive constructive policy implications for crop diversity and the transformation processor of agriculture towards commercialization.

Another potential area for the future research is to analyse the empirical implications of land fragmentation on farm households' decision-making process and crop intensification. As farm land size is considerably small in Afghanistan and is expected to further shrink over time due to rapid increase in population and urbanization, the implications of farm size can alter over time and the overall well-being of farming remains an important aspect that needs to be empirically addressed. This is especially of great interest as crop diversity significantly increases with farm size.

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VI. Appendix

6.1. Annex I: Summary Statistics & Characteristics of farms

Table A1: Crop revenue share and growing frequency

Ranked by growing frequency		Ranked by the share of revenue	
Crop	Growing Frequency	Crop	Revenue share (%)
Wheat	7,961	Wheat	49.50
Maize	2,783	Rice	11.79
Fodder	1,564	Maize	11.42
Potatoes	1023	Potatoes	5.49
Rice	549	Onions	5.17
Barley	548	Cotton	3.01
Beans	419	Melons	2.70
Onion	377	Fodder Crops	2.46
Other Vegetables	224	Beans	1.76
Tomatoes	202	Tomatoes	1.58
Millet	179	Other Vegetables	1.49
Sugar beet/cane	128	Barley	1.46
Melons	121	Okra	0.64
Cotton	113	Millet	0.50
Okra	105	Eggplant	0.33
Eggplant	41	Other Fruits	0.23
Courgette	40	Tree Fruits	0.12
Tree fruits	13	Sugar beet/cane	0.12
Cumin	9	Nuts	0.10
Flax	8	Cumin	0.07
Nuts	7	Flax	0.04
Other fruits	7	Courgette	0.02
N	8,613		8,613

Source: Author's calculations of the ALCS 2013-14 data

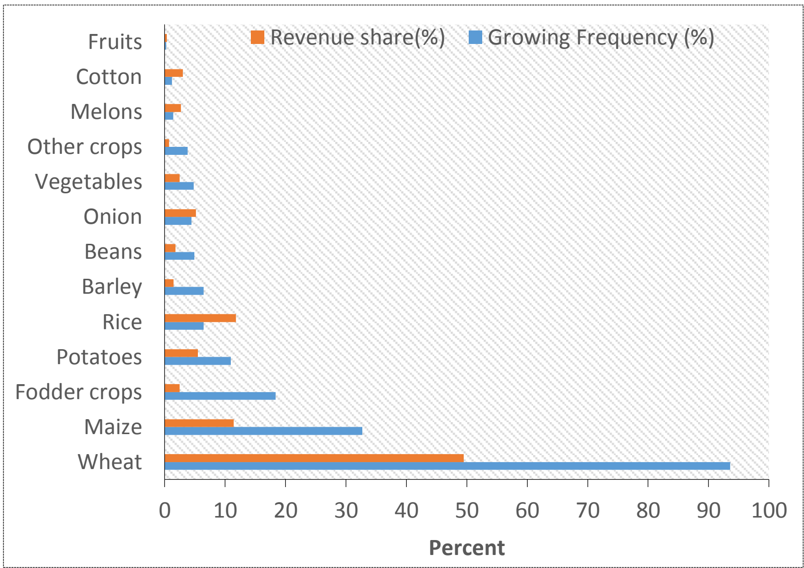

Figure A 1: Crop growing frequency and revenue share
Source: Author's calculations of the ALCS 2013-14

Table A 1: Single croppers (farmers who grow one and only one crop)

Crop	Growing frequency	Percent	% of total sample (N=8,864)
Wheat	2,539	82.73	28.70
Maize	129	4.20	1.46
Fodder crops	125	4.07	1.41
Potatoes	93	3.02	1.05
Barley	40	1.30	0.45
Other vegetables	23	0.75	0.26
Melons	22	0.72	0.25
Onions	21	0.68	0.24
Rice	19	0.62	0.21
Tomatoes	14	0.46	0.16
Millet	13	0.42	0.15
Beans	12	0.39	0.14
Cotton	10	0.33	0.11
Okra	3	0.10	0.03
Sugar beet/cane	3	0.10	0.03
Cumin	2	0.07	0.02
Nuts	1	0.03	0.01
Courgette	1	0.03	0.01
Flax	-	-	-
Eggplant	-	-	-
Tree fruits	-	-	-
Other fruits	-	-	-
Total	3,070		

Note: Note total sample size is 8,853. Single croppers (farm household who grow one and only crop) except for farmers who grow basic staple crops such as wheat, maize, rice, and barley are excluded. This means that 240 observations are dropped, reducing the sample from 8,853 to 8,521 households. These farmers are assumed to be part-time farmers who are mainly involved in off-farm activities but growing garden crops.

Source: Author's calculations of the ALCS 2013-14

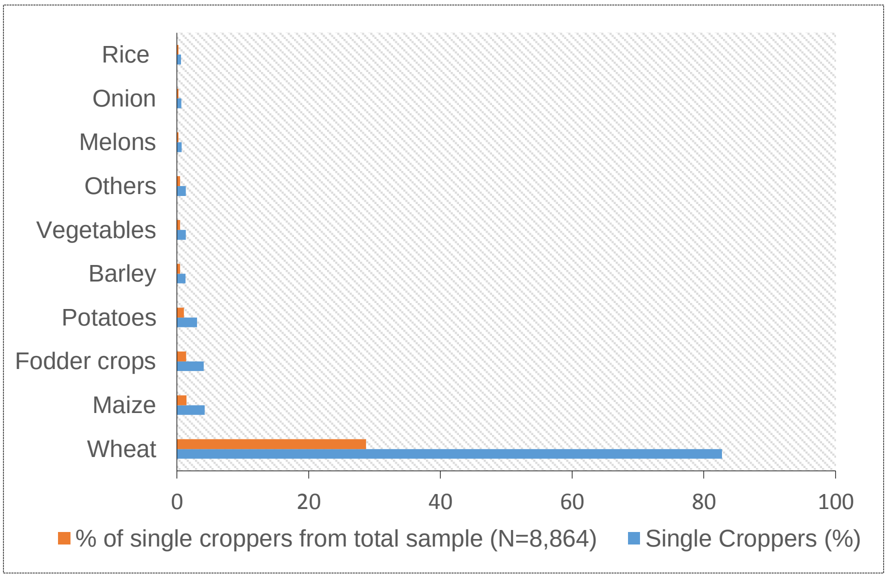

Figure A 2: Single croppers (farmers who grow one and only one crop)

Source: Author's calculations of the ALCS 2013-14

Table A 2: Characteristics of farm household by access to off-farm income

	No Off-farm Income		Off-farm Income		T-Test of Mean Difference	
Characteristic	Mean	SD	Mean	SD	Difference	t-val
Total Land (Ha)	2.030	6.16	1.290	2.42	0.74***	-6.45
Farm income (10K)	8.230	9.13	2.380	4.42	5.85***	-33.87
THI (0≤THI≤1)	0.300	0.23	0.270	0.24	0.02***	-4.7
CEI (0≤CEI≤1)	0.312	0.22	0.280	0.24	0.03***	-5.36
Cattle ownership (N)	1.550	2.32	1.430	1.68	0.11*	-2.42
Oxen ownership (N)	0.310	0.72	0.210	0.57	0.09***	-6.11
Tractor ownership (N)	0.040	0.2	0.060	0.25	-0.02***	(-4.04)
Distance to road (10km)	2.640	3.27	1.970	2.94	0.67***	-9.57
Opium share by province (%)	0.060	0.13	0.010	0.06	0.04***	-17.26
Irrigation water (1=access)	0.410	0.49	0.470	0.5	-0.06***	(-5.20)
Communication Equip. (1=access)	0.740	0.44	0.830	0.37	-0.10***	(-10.24)
Transport Equip (1=access)	0.470	0.5	0.440	0.5	0.03**	-2.9
Extension Services (1=access)	0.120	0.33	0.220	0.41	-0.10***	(-12.5)
Landscape (1=open plain)	0.410	0.49	0.450	0.5	-0.04***	(-4.06)
N	3,184		5,429		8,613	

Source: Author's calculations of the ALCS 2013-14

Table A 3: Characteristics of farm household that grow one and only one crop (except for basic staple crops such as wheat, maize, rice, barley, potato, cotton, and onion) vs households who grow a mix of crops

	Mix of Crops		One and Only One crop		T-test	
Variable	Mean	SD	Mean	SD	Difference	t
Total Land (Jeribs)	1.560	4.23	0.66	1.11	0.90***	-10.66
Distance to Road (km)	2.220	3.09	1.94	2.84	0.28	-1.48
Off-farm Income (10K AFN)	5.520	11.1	8.08	9.88	-2.56***	(-3.95)
Farm Income (10K AFN)	4.540	7.15	2.63	5.06	1.91***	-5.70
CDI (0≤THI≤1)	0.280	0.23	0.00	0.00	0.28***	-112.97
CEI (0≤THI≤1)	0.290	0.23	0.00	0.00	0.29***	-117.60
Cattle Ownership (Number)	1.480	1.94	0.96	1.23	0.52***	-6.33
Oxen Ownership (Number)	0.250	0.64	0.08	0.36	0.17***	-6.88
Tractor Ownership (Number)	0.050	0.23	0.02	0.13	0.04***	-4.13
Extension Services (1=access)	0.180	0.39	0.20	0.40	-0.01	(-0.47)
Transport Equip. (1=yes)	0.450	0.50	0.38	0.49	0.07*	-2.10
Communication Equip. (1=yes)	0.800	0.40	0.87	0.34	-0.07**	(-3.30)
Irrigation water (1=access)	0.450	0.50	0.54	0.50	-0.09**	(-2.74)
Landscape (Open Plan=1)	0.440	0.50	0.52	0.50	-0.08*	(-2.43)
Fertilizer Expenditures (AFN)	4,630	8900	2,402	3,525	2,228***	-10.20
N	8,613		240		8,853	

Source: Author's calculations of the ALCS 2013-14

Table A 4: Groups of farm household and number of crops

Number of Crops	Number of Farms	Percent
1	2,830	32.86
2	4,110	47.65
3	1,410	16.37
4 or more	269	3.12
Mean	1.91	
Min	1	
Median	2	
Max	6	
N	8,613	

Source: Author's calculations of the ALCS 2013-14

Table A 5: Crop activity across Agro-Ecological Zones (AEZ)

AEZ	Grains	Fodder crops	Potato	Vegetables	Beans	Onions	Industrial crops	Melons	Fruits	Nuts
NEM	275	6	17	0	8	14	0	2	0	0
CM	1,690	358	569	16	38	9	5	2	2	2
HFL	453	26	0	29	3	19	3	21	1	2
SMF	2,223	697	254	79	134	118	7	29	7	1
HVSB	1,367	5	5	14	1	2	49	20	2	0
TP	741	137	1	34	1	4	31	16	0	0
NMF	2,325	168	55	123	8	85	133	28	3	0
EMF	2,946	168	122	317	226	126	20	3	6	2
Overall	12,020	1,565	1,023	612	419	377	248	121	21	7

Source: Author's calculations of the ALCS 2013-14

Table A 6: Summary statistics of variables by number of crops

Variable	All Farmers		1 crop		2 Crops		3 Crops		4 or more crops	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
CEI (0≤CEI≤1)	0.298	0.232	-	-	0.401	0.113	0.515	0.121	0.621	0.112
THI (0≤CEI≤1)	0.286	0.232	-	-	0.379	0.131	0.506	0.133	0.631	0.117
Total Land (Ha)	1.576	4.248	1.164	2.256	1.704	5.318	1.814	2.716	2.561	6.803
Household Head Sex (0=F, 1=M)	0.995	0.068	0.992	0.089	0.997	0.058	0.998	0.046	1.000	-
Household Head Age (Years)	44.16	13.912	43.74	14.12	44.102	13.9	44.92	13.62	45.33	13.56
Household Head Age Square (Years)	2,144	1,333	2,112	1,362	2,138	1,322	2,203	1,318	2,238	1,267
No Formal Schooling (1=Yes, 0 Otherwise)	0.771	0.420	0.818	0.386	0.750	0.433	0.760	0.427	0.654	0.476
Primary & Lower Secondary (1=Yes, 0=Otherwise)	0.115	0.319	0.100	0.300	0.118	0.322	0.134	0.341	0.138	0.345
Upper Secondary (1=yes, 0=Otherwise)	0.078	0.268	0.054	0.226	0.091	0.287	0.077	0.266	0.138	0.345
Teacher College (1=yes, 0=Otherwise)	0.022	0.148	0.017	0.129	0.026	0.160	0.016	0.124	0.056	0.230
University & Postgrad (1=yes, 0=Otherwise)	0.013	0.115	0.011	0.104	0.015	0.121	0.014	0.118	0.015	0.121
Household Size (Persons)	8.135	3.483	7.568	3.305	8.362	3.599	8.478	3.283	8.632	3.755
Quality of Land (1=High, 0=Low)	0.749	0.433	0.675	0.469	0.799	0.401	0.760	0.427	0.699	0.460
Cattle Ownership (Heads)	1.484	1.950	1.194	1.711	1.518	1.838	1.860	2.557	1.955	1.757
Oxen Ownership (Number)	0.250	0.638	0.206	0.533	0.214	0.571	0.418	0.895	0.372	0.803
Tractor Ownership (Number)	0.053	0.232	0.022	0.145	0.068	0.260	0.070	0.279	0.041	0.198
Access to Info Equipment (0=No, 1=Yes)	0.797	0.403	0.740	0.439	0.817	0.387	0.838	0.368	0.848	0.360
Own Transport Equipment (0=No, 1=Yes)	0.452	0.498	0.456	0.498	0.427	0.495	0.523	0.500	0.420	0.494
Access to Irrigation (0=No, 1=Yes)	0.446	0.497	0.373	0.484	0.481	0.500	0.452	0.498	0.628	0.484
Landscape 1: Valleys & Hills (1=Yes, 0=Otherwise)	0.562	0.496	0.642	0.479	0.497	0.500	0.617	0.486	0.439	0.497
Landscape 2: Open Plain (1=Yes, 0=Otherwise)	0.438	0.496	0.358	0.479	0.503	0.500	0.383	0.486	0.561	0.497
Total Off-Farm Income (10,000 AFN)	5.511	11.088	5.714	8.654	5.650	11.382	4.974	14.610	4.127	5.726
Extension Services (1=Access, 0=Otherwise)	0.182	0.386	0.155	0.362	0.212	0.409	0.158	0.365	0.145	0.353
Distance to Market (1=Not Reachable, 0 Otherwise)	0.043	0.202	0.056	0.230	0.038	0.191	0.035	0.183	0.026	0.159
Distance to Market (1=Less than 1h, 0 Otherwise)	0.548	0.498	0.519	0.500	0.566	0.496	0.523	0.500	0.695	0.461
Distance to Market (1=More than 1h, 0 Otherwise)	0.410	0.492	0.425	0.494	0.396	0.489	0.443	0.497	0.279	0.449
Distance to Nearest Road (10 km)	2.220	3.089	2.608	3.438	2.045	2.895	2.167	2.990	1.243	2.117
Agro-Ecological Zone 1: NEM (1=NEM, 0=Otherwise)	0.024	0.152	0.044	0.206	0.011	0.106	0.019	0.137	0.022	0.148
Agro-Ecological Zone 2:CM (1=CM, 0=Otherwise)	0.163	0.369	0.180	0.385	0.136	0.343	0.216	0.411	0.108	0.311
Agro-Ecological Zone 3: HFL (1=HFL, 0=Otherwise)	0.041	0.198	0.064	0.244	0.034	0.182	0.018	0.135	0.022	0.148
Agro-Ecological Zone 4: SMF (1=SMF, 0=Otherwise)	0.197	0.398	0.109	0.312	0.229	0.420	0.303	0.460	0.056	0.230
Agro-Ecological Zone 5: HVSB (1=HVSB, 0=Otherwise)	0.106	0.308	0.132	0.339	0.126	0.332	0.016	0.127	-	-
Agro-ecological Zone 6:TP (1=TP, 0=Otherwise)	0.068	0.251	0.089	0.284	0.072	0.258	0.024	0.153	0.022	0.148
Agro-ecological Zone 7: NMF (1=NMF, 0=Otherwise)	0.186	0.389	0.225	0.417	0.165	0.371	0.160	0.367	0.249	0.433
Agro-ecological Zone 8:EMF (1=EMF, 0=Otherwise)	0.216	0.412	0.157	0.364	0.227	0.419	0.243	0.429	0.520	0.501
N	8,613		2,830		4,104		1,410		269	

Source: Author's calculations of the ALCS 2013-14

6.2. Annex II: Alternative econometric models

Table A 7: ME of Tobit and IV-Tobit model using THI as a dependent variable

Dependent variable: THI	**Tobit**		**IV-Tobit**	
	ME	SE	ME	SE
Off-farm Income (10,000 AFN)	-0.002***	0.000	-0.015***	0.001
Total Land (Ha)	0.004***	0.001	0.003***	0.001
Transport Equipment (1=access)	0.020***	0.006	0.030***	0.007
Communication Equipment (1=access)	0.015**	0.007	0.025***	0.008
Cattle Ownership (N)	0.006***	0.001	0.003**	0.002
Oxen & Yaks (N)	0.036***	0.004	0.024***	0.005
Tractor & Thresher (N)	0.031***	0.011	0.046***	0.013
Land Quality (1=good)	0.049***	0.008	0.049***	0.009
Landscape (1=open plain)	0.052***	0.006	0.061***	0.007
Sufficient Irrigation Water (1=access)	0.024***	0.006	0.029***	0.006
Household Size (persons)	0.006***	0.001	0.013***	0.001
HH Head Edu (1=primary & lower sec)	0.014*	0.008	0.039***	0.010
HH Head Edu (2=upper secondary)	0.027***	0.010	0.085***	0.013
HH Head Edu (1=teacher college)	0.000	0.017	0.040*	0.020
HH Head Edu (1=university & graduate)	0.015	0.023	0.123***	0.030
HH Head Sex (1=male)	0.097***	0.033	0.077**	0.039
HH Head Age (years)	0.000	0.000	0.000	0.000
Extension Services (1=access)	-0.012*	0.007	-0.016**	0.008
Distance to Nearest Road (10 km)	-0.004***	0.001	-0.005***	0.001
Distance to Market (1=less than 1 hr)	0.007	0.013	0.029**	0.015
Distance to Market (2=more than 1 hr)	0.023*	0.013	0.015	0.014
Agro-Ecological Zone 1 (NEM)	0.074***	0.016	0.036*	0.019
Agro-Ecological Zone 2 (CM)	-0.004	0.019	-0.025	0.022
Agro-Ecological Zone 3 (HFL)	0.130***	0.017	0.120***	0.020
Agro-Ecological Zone 4 (SMF)	0.038**	0.017	-0.046**	0.021
Agro-Ecological Zone 5 (TP)	-0.028*	0.017	-0.065***	0.021
Agro-Ecological Zone 6 (NMF)	0.097***	0.016	0.061***	0.020
Agro-Ecological Zone 7 (EMF)	0.182***	0.017	0.161***	0.020
Log-Likelihood	-3,900.48		-35,874.70	
Wald Test of exogeneity (chi2, p-value)	-	-	168.73***	0.000
Amemiya-Lee-Newey statistic (chi2, p-value)	-	-	0.230	0.629
Left censored observations(N)	2,830		2,830	
Uncensored observations (N)	5,782		5,782	
N	8,613		8,613	

*Note: significance levels indicated by * p<0.10, ** p<0.05, *** p<0.010. Marginal Effects for factor levels is the discrete change from the base level. The omitted categories are: no access for transport equipment, no access for communication equipment, rain-fed land alone for land quality, hills and valleys for landscape, no access to sufficient irrigation water for irrigation, no formal schooling for education, no access for extension services, female for head sex, not reachable for distance to market, and agro-ecological zone 8*

Table A 8: Average marginal effects probit and instrumental variable probit

Dependent variable: CEI	**Probit**		**IV-Probit**	
	ME	se	ME	se
Off-farm Income (10,000 AFN)	-0.003***	0.000	-0.070***	0.009
Total Land (Ha)	0.026***	0.002	0.051***	0.014
Transport Equipment (1=access)	0.022**	0.011	0.104***	0.031
Communication Equipment (1=access)	0.006	0.013	0.065*	0.034
Cattle Ownership (N)	0.009***	0.003	0.012	0.008
Oxen & Yaks (N)	0.062***	0.009	0.096***	0.025
Tractor & Thresher (N)	0.108***	0.027	0.319***	0.082
Land Quality (1=good)	0.088***	0.015	0.219***	0.042
Landscape (1=open plain)	0.117***	0.012	0.328***	0.035
Sufficient Irrigation Water (1=access)	0.036***	0.010	0.106***	0.029
Household Size (persons)	0.010***	0.002	0.059***	0.010
HH Head Edu (1=primary & lower sec)	0.027*	0.016	0.190***	0.047
HH Head Edu (2=upper secondary)	0.067***	0.018	0.431***	0.058
HH Head Edu (1=teacher college)	0.010	0.033	0.217***	0.083
HH Head Edu (1=university & graduate)	0.019	0.043	0.531***	0.146
HH Head Sex (1=male)	0.153**	0.077	0.244	0.174
HH Head Age (years)	-0.000	0.000	0.001	0.001
Extension Services (1=access)	-0.007	0.013	-0.045	0.035
Distance to Nearest Road (10 km)	-0.003*	0.002	-0.013***	0.004
Distance to Market (1=less than 1 hr)	-0.017	0.024	0.062	0.056
Distance to Market (2=more than 1 hr)	0.036	0.023	0.053	0.054
Agro-Ecological Zone 1 (NEM)	0.218***	0.037	0.266***	0.086
Agro-Ecological Zone 2 (CM)	0.028	0.044	-0.069	0.147
Agro-Ecological Zone 3 (HFL)	0.345***	0.037	0.722***	0.094
Agro-Ecological Zone 4 (SMF)	0.060	0.041	-0.338***	0.107
Agro-Ecological Zone 5 (TP)	0.014	0.042	-0.162	0.100
Agro-Ecological Zone 6 (NMF)	0.217***	0.037	0.287***	0.087
Agro-Ecological Zone 7 (EMF)	0.312***	0.037	0.585***	0.095
Log-Likelihood	-4,937.57		-36,899.05	
/athrho2_1	-	-	0.805***	0.097
/lnsigma2	-	-	2.304***	0.162
Wald Test of exogeneity (chi2, p-value)	-	-	211.52***	0.000
Amemiya-Lee-Newey statistic (chi2, p-value)	-	-	1.570	0.210
N	8,613		8,613	

*Note: significance levels indicated by * p<0.10, ** p<0.05, *** p<0.010. Marginal Effects for factor levels is the discrete change from the base level. The omitted categories are: no access for transport equipment, no access for communication equipment, rain-fed land alone for land quality, hills and valleys for landscape, no access to sufficient irrigation water for irrigation, no formal schooling for education, no access for extension services, female for head sex, not reachable for distance to market, and agro-ecological zone 8*

Table A10: Maximum likelihood estimation of the MNL choice model

	Two Crops		Three Crops		Four or more crops	
Variable	**b**	**se**	**b**	**se**	**b**	**se**
Off-farm Income (in 10,000 AFN)	-0.016***	0.003	-0.042***	0.005	-0.094***	0.014
Total Land (Ha)	0.198***	0.019	0.215***	0.020	0.222***	0.021
Transport Equip (1=access)	0.083	0.060	0.220***	0.081	0.143	0.166
Communication Equip (1=access)	-0.054	0.068	0.282***	0.097	0.281	0.195
Cattle Ownership (N)	0.026	0.016	0.095***	0.019	0.071**	0.032
Oxen & Yaks (N)	0.216***	0.051	0.487***	0.058	0.358***	0.104
Tractor//Threshers (N)	0.566***	0.153	0.666***	0.181	0.940***	0.333
Land Quality (1=both irrigated and rain fed)	0.491***	0.081	0.491***	0.106	-0.308	0.204
Landscape (1=open plain)	0.595***	0.066	0.494***	0.087	0.862***	0.163
Sufficient Irrigation Water (1=access)	0.165***	0.056	0.095	0.076	0.864***	0.152
Household Size (persons)	0.048***	0.009	0.070***	0.012	0.091***	0.021
HH Head Edu (1=primary)	0.120	0.086	0.250**	0.110	0.313	0.205
HH Head Edu (2=secondary)	0.399***	0.107	0.234*	0.142	0.810***	0.221
HH Head Edu (3=teacher college)	0.189	0.181	-0.359	0.268	0.753**	0.333
HH Head Edu (4=university & graduate)	0.116	0.237	0.266	0.308	0.042	0.570
Head Age (years)	-0.008	0.011	-0.002	0.015	0.026	0.029
Head Age Squared	0.000	0.000	0.000	0.000	-0.000	0.000
Extension Services (1=access)	0.098	0.070	-0.338***	0.098	-0.668***	0.195
Distance to Nearest Road (10 km)	-0.009	0.009	-0.022*	0.012	-0.115***	0.033
Distance to Market (1=less than 1hr)	-0.139	0.125	0.009	0.186	0.361	0.413
Distance to Market (1=2=more than 1hr)	0.129	0.123	0.330*	0.183	0.235	0.412
Agro-Ecological Region 1 (CM)	0.987***	0.189	0.946***	0.238	0.110	0.474
Agro-Ecological Region 2 (HFL)	0.292	0.219	-0.670**	0.319	-0.755	0.619
Agro-Ecological Region 3 (SMF)	1.705***	0.195	1.735***	0.246	-0.366	0.526
Agro-Ecological Region 4 (HVSB)	0.581***	0.203	-1.925***	0.327	-16.339	451.209
Agro-Ecological Region 5 (TP)	0.254	0.210	-1.307***	0.308	-2.141***	0.644
Agro-Ecological Region 6 (NMF)	1.060***	0.191	0.552**	0.245	0.535	0.461
Agro-Ecological Region 7 (EMF)	1.503***	0.193	1.338***	0.246	1.582***	0.460
Constant	-1.834***	0.315	-3.309***	0.432	-5.069***	0.866
Base Outcome	One Crop					
Log-Likelihood	-8,728.57					
chi2	1,915.298					
p	0.000					
Pseudo R2	0.099					
N	8,624					

*Note: significance levels indicated by * p<0.10, ** p<0.05, *** p<0.010 Marginal Effects for factor levels is the discrete change from the base level. The omitted categories are: no access to transport equipment, no access for communication equipment, rain-fed land alone for land quality, hills and valleys for landscape, no access to sufficient irrigation water, no formal education, not reachable for distance to market, and agro-ecological zone 8, none for extension services*