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Analysis

Seeds for livelihood: Crop biodiversity and food production in Ethiopia

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ABSTRACT

This paper uses a farm level panel data from Ethiopia and a comprehensive empirical strategy to investigate the contribution of crop biodiversity on food production. We find that increasing the number of crop variety increases production. This result is stronger when rainfall level is lower. Moreover, the productivity analysis is complemented with the study of the determinants of farm level crop biodiversity. Empirical results suggest that rainfall, tenure security and household endowments tend to govern crop diversity decisions at the farm level.

1. Introduction

Crop biodiversity is the foundation of food production and supply. Farmers and breeders use biodiversity to adapt crops to different and changing production environments. Maintaining diverse plant varieties on farmers' fields, *in-situ*[1] conservation, *vis-a-vis* storing germplasms in gene banks, is increasingly regarded as an effective way of conservation of plant genetic resources (Benin et al., 2004; Bezabih, 2008). At the heart of whether *in-situ* conservation could be pursued as a fruitful strategy of keeping important germplasms alive is whether it generates farm level benefits that are internalized by farmers. Benin et al. (2004) observed that on farm conservation of crop diversity poses obvious policy challenges in terms of the design of appropriate incentive mechanisms and possible trade-offs between conservation and productivity.[2] There is evidence, however, of that crop biodiversity is very important for both the functioning of ecological systems and the generation of ecosystems' services (e.g., Tilman and Downing, 1994; Tilman et al., 1996; Wood and Lenné, 1999; Loreau and Hector, 2001; Naeem et al., 1994).

Growing multiple species makes possible the productive exploitation of synergies among crops and niche partitioning (Di Falco and Chavas, 2009). This has been reported in a series of experimental studies that have shown that plant biomass is an increasing function of diversity (Tilman and Downing, 1994; Tilman et al., 1996; Lehman and Tilman, 2000) and that higher diversity systems give greater yields than lower ones (Tilman et al., 2005). These results can be stronger in a setting where agro-ecological heterogeneity and harsh weather conditions may increase positive interactions among plants. Plants can exhibit a greater reliance on positive synergies and display facilitation (rather than competition).[3] The implication is that conserving diversity in the field delivers important productive services and allows farmers to mitigate some of the negative effects of harsh weather and agro-ecological conditions (Walker et al., 1999; Di Falco and Chavas, 2009).

Besides the evidence based on experimental analysis, a growing body of applied economics literature focusing on the same research question, but using different methods, found similar evidence. The role of biodiversity on food production is found to be positive and not negligible (e.g. Di Falco et al., 2007; Smale et al., 1998). These findings are based on two different empirical approaches: aggregate panel data and farm level cross section analyses. The aggregate panel data analysis makes use of regional or district level data to estimate aggregate production functions where biodiversity is typically modelled as an input in the production process (e.g. Smale et al., 1998; Widawsky and

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[1] Conservation of genetic resources *in-situ* refers to the continued cultivation and management by farmers of crop populations in the open, genetically dynamic systems where the crop has evolved.

[2] Smale et al. (2003) noted that there is a fundamental problem that affects the design of policies to encourage on farm conservation. Crop genetic diversity is an impure public good, meaning that it has both private and public economic attributes.

[3] Bertness and Callaway (1994), Callaway (1995), Callaway and Walker (1997), and Vandermeer (1989).

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Rozelle, 1998). These studies exploit the benefits of fixed effects panel data in terms of removing time invariant unobserved heterogeneity. However, the scale of these analyses does not allow controlling for farm agro-ecological characteristics and implicitly assumes that the underlying theoretical model can be scaled up at a macro level. The second approach of using farm level cross section analysis, while overcoming the aggregation problem, has the obvious shortcoming of neglecting dynamics (Di Falco and Chavas, 2009).

In this paper we build upon these previous contributions and assess the contribution of crop diversity to farm level productivity using farm level panel data from the Central Highlands of Ethiopia. The dataset was formed from a survey of 1500 farm households in Ethiopia collected in 2002 and 2005 The adoption of a farm level panel data, besides helping in dealing with endogeneity, allows us to address the issue of time invariant heterogeneity at the household level (i.e. farmers ability, or farm specific unobserved characteristics). Compared to the existing literature, this will provide further (and more robust) empirical evidence on the relationship between productivity and crop biodiversity. The study is conducted in a setting where environmental conditions are difficult due to poor soil quality and challenging weather conditions. The drought-prone and moisture-stressed production environment of Ethiopia. This is a rain-fed production environment. Therefore, of special interest is the impact of rainfall abundance on productivity and its interplay with crop biodiversity. To this end, we matched the farm level data with data on the current and lagged levels of rainfall. To our knowledge no farm level panel has investigated the productive implications of the interaction between biodiversity and weather.[4] We employ a comprehensive empirical strategy that both assesses the relationship between productivity, diversity and rainfall, and addresses the possible endogeneity of diversity in productivity. We first estimate two separate equations representing farm productivity and the determinants of biodiversity, respectively. This entails the assumption that diversity is not endogenous in the productivity equation. Second we adopt a pseudo-fixed effects approach to control for possible endogeneity of diversity and time invariant unobserved heterogeneity. Third, we jointly estimate the diversity and productivity equations, to address the possible endogeneity of diversity due to factors other than time invariant unobserved heterogeneity and to further probe the robustness of our findings. Moreover the first stage regression provides useful information on the determinants of crop biodiversity at the farm level including tenure security. The availability of data regarding both past and current rainfall can also capture the role of expected and observed weather on crop choice and shed light on the way farmers use *in-situ* diversity (Van Dusen and Taylor, 2005; Benin et al., 2004) in food production.

The rest of the paper is organized as follows. In Section 2, we provide a brief background. Section 3 provides information about the Ethiopian agriculture and agro-biodiversity in the country. The estimation methodology along with some considerations in the estimation procedure is provided in Section 4. Section 5 details the survey design and data employed in the empirical analysis. Section 6 presents the empirical findings and Section 7 concludes the paper.

2. Background

Screening both ecological and resource economics literature, three mechanisms have been identified that relate crop biodiversity to agro-ecosystem functioning and productivity. First, biodiversity increases the level at which certain ecosystem services are provided. Compared to a single species (or a less diverse) ecosystem, in diverse ecosystems there is a greater likelihood that key species that have large impact on the performance of an ecosystem would be present in the system. This is known as the 'sampling effect' or the 'selection probability effect' (Aarssen, 1997; Huston, 1997; Loreau, 2000; Tilman et al., 2001). Second, diversity enhances the possibility of species complementarities. Complementarities among crop species imply an efficient use of total available resources both in time and space (Trenbath, 1974; Harper, 1977; Ewel, 1986; Vandermeer, 1989; Loreau, 2000). Multiple crop species can also reduce the implication of price and production risk (Baumgärtner and Quaas, 2008; Di Falco and Chavas, 2009) and allows farmers to market their produce several times throughout the year. Third, diversity increases facilitative interaction among species by ensuring the presence of species with different sensitivities to suite environmental conditions (Bertness and Callaway, 1994; Mulder et al., 2001). Since certain species can buffer against harsh environmental conditions or provide a critical resource for other, the probability that some of these species can react in a functionally differentiated way to external disturbance of the system and changing environmental conditions increases with increasing number of functionally different species. Therefore, biodiversity can act as an insurance in carrying out ecological processes (Borrvall et al., 2000; Elton, 1958; Chapin and Shaver, 1985; Hooper et al., 1995; Lawton and Brown, 1993; MacArthur, 1955; Naeem, 1998; Naeem and Li, 1997; Petchey et al., 1999; Trenbath, 1999; Baumgärtner and Quaas, 2009).[5]

The level of complementarity and inter-specific facilitation between species is, however, dependent on the extent of both spatial and temporal heterogeneity in the system. Tilman et al. (2005), for instance, demonstrate that under homogeneous environment, a single species best adapted to the environmental condition will produce greatest biomass. With heterogeneous habitats, however, diversity tends to be more beneficial. Norberg (2001) present a similar but a more comprehensive approach of multispecies competition that relates aggregate biomass, average phenotype (a measure of environmental responsiveness) and environmental variability. The framework developed by Norberg (2001) suggest that phenotypic variance within functional groups is linearly related to their ability to respond to environmental changes. As a result, the long-term productivity for a group of species with high phenotypic variance may be higher than for the best single species.

Whatever the sources of the value of crop biodiversity we test the hypothesis that the correlation between diversity and productivity is positive. In order to control for environmental conditions, rainfall and other source of observed farm specific heterogeneity (e.g. slope of the plots or fertility) are inserted into the analysis. We also include some interaction terms between biodiversity and the variables representing these conditions. This, for instance, allows to understand the interplay between biodiversity and rainfall and tests the hypothesis that the productive benefits of biodiversity are more important when rainfall is lower, thus the amount of environmental stress is larger.[6]

We extend the set of tested hypothesis by providing an analysis of the determinants of farm diversity. Understanding the drivers of on farm diversity is very important for the policy standpoint. It has been found that in the presence of market imperfections, farmers' choice on

[4] Some evidence has been provided at more aggregate level, see Di Falco and Chavas (2008).

[5] For a comprehensive assessment of the contribution of diversity to ecosystem functioning, see Hooper et al. (2005).

[6] Based on crops grown in Ethiopia, a number of agronomic and other biophysical studies show that different crops respond differently to moisture availability. Using geospatial rainfall estimates and seasonal water balances, Senay and Verdin (2003) show that teff, maize and sorghum respond differently to moisture availability. In their study of responsiveness of alternative durum wheat cultivars, Simane et al. (1993) found that the variation in moisture stress led to significant differences in yield measures. In addition, Yadeta and Bejiga (2004) highlight differences in drought responsiveness among 482 genotypes of chickpea evaluated for differences in drought responsiveness. In Sinebo (2005), sixteen barley genotype grain yields were shown to interact differently with different experimental environments. The effect of mixtures of cultivars on yield and risk distribution in four maize cultivars grown at four different population levels also indicated biomass production differs with rainfall availability (Tilahun, 1995). Kefale and Ranamukhaarachchi (2006) show that three maize varieties respond negatively but differently to moisture deficit.