Agricultural Biodiversity and Land Fragmentation: the Case of Bulgaria

By

Salvatore Di Falco[i]*, Ivan Penov[ii] Aleksi Aleksiev[ii] and Tom M. van Rensburg[iii]

Abstract:

This paper presents an empirical analysis of the role of land fragmentation, crop biodiversity and their interplay with farm profitability. Original primary data are drawn from a survey conducted in Bulgaria. We present two different estimation methods: Seemingly Unrelated Regression and Three Stages Least Squares. The econometric results stress the ambiguous role of land fragmentation on farm profitability. On one hand, land fragmentation reduces farm profitability. On the other hand, land fragmentation fosters crop diversification. Biodiversity also plays a beneficial role in farm profitability. Policies that aim to reduce land fragmentation may overlook the positive link between diversity and plot heterogeneity.

[i] KBS, University of Kent UK
[ii] Agricultural University of Plovdiv – Bulgaria

[ii] Agricultural University of Plovdiv – Bulgaria

[iii]Department of Economics, National University of Ireland, Galway, Republic of Ireland

* Contact author. Address: Room 20 Orwin Building, KBS Wye Campus, Wye Ashford Kent, TN25 5AH Kent UK. Email: s.difalco@kent.ac.uk

Introduction

Land fragmentation, where a single farm comprises numerous individual parcels of land is a common agrarian feature of many transition economies as well as developing countries (Blarel et al., 1992; Dijk, 2002; Sabastes-Wheeler, 2002; Todorova and Lulcheva, 2005; Niroula and Thapa, 2007). During the 1990s, Central and Eastern European countries conducted land reforms. The main elements of reform were land restitution, privatization and dissolution of large centrally run agricultural enterprises (Lerman, 1999; Davidova, 1997; Dijk, 2002: Kopeva, 2001). Land fragmentation is often considered to be an obstacle for improving agricultural productivity and preventing land abandonment (Theesfeld, 2005; Dirimanova, 2006). It is thought to impede growth and prevent efficiency gains in the agricultural sector and many governments including Bulgaria have sought to promote a more rational spatial allocation of land and formulated policies aimed at encouraging land consolidation (Blarel et al., 1992; Hung et al., 2007).

Although it has been argued that land fragmentation may be detrimental to both farmers and the economy, there are a number of reasons why farmers may benefit from land fragmentation. Land fragmentation provides a means of exploiting land parcels of differing quality. This facilitates crop diversification, spreads labour requirements, reduces production and price risks and better matches soil types with necessary food crops (Bently, 1987; Blarel et al., 1992). Land fragmentation is thought to promote crop and agricultural diversity[1] (Bellon and Taylor, 1993; Hung, 2006). Bulgaria is a prime example of such a situation. After the land reform in 1991, agricultural production characteristics have changed dramatically. The mode of agricultural production has gone from large specialized production units to highly fragmented private farms.

The focus of this paper is on analyzing the implications of land reform for both farm profitability and agro-biodiversity. While land fragmentation can be expected to have a negative effect on farm profitability, since it increases costs of control of organizing agricultural production it can also positively affect the level of crop diversification present on any given farm. Farmers may be induced to increase crop biodiversity in order to match different agro-ecological conditions or quality of the plots they manage. Moreover, farmers can take advantage of this *de-facto* diversification and grow products that would be marketed at different periods during the year. Land reform has generated similar problems in other CEECs. The linkages between land fragmentation, crop biodiversity and farm profitability are, thus, crucial in the agricultural system of CEEC countries.

While there is some empirical evidence on how land parcel fragmentation influences farm productivity and profitability (Blarel et al., 1992; Niroula and Thapa, 2005; Niroula and Thapa, 2007), the consequent implication of the higher level of crop diversity on farming profitability has not been analyzed before. This paper aims to fill this gap. To this end we adopt a structural approach that takes into account the recursive and simultaneous nature of the problem. Land fragmentation jointly determines farm profits and farm crop diversification and biodiversity. Moreover, "on farm biodiversity" in turn can affect farm profitability. We, thus, need to extend the analysis by considering also the potential endogeneity of crop biodiversity. The research questions that we attempt to answer in this study are:

(i) to assess whether land fragmentation reduces farm productivity and profitability due to an inefficient spatial allocation of land;
(ii) to determine whether land fragmentation affects crop diversity and the number and varieties of crops grown.

Results will also contribute to the on going debate on the productive role of biodiversity in agriculture. The paper proceeds as follows: first a detailed historical account of land reform and land fragmentation is given; second a description of the survey instrument and methodological approach is provided; third the empirical approach used to explore the relationship between land fragmentation agrobiodiversity and farm profitability is discussed and the results presented and finally some conclusions are drawn.

Background

In Bulgaria prior to transition, farming was a centralized activity. Large productive units that privileged high crop specialization dominated the agricultural landscape. Private farming was allowed only on small plots, and individual farmers were still very dependent on co-operatives for farm inputs and output realization.

Land reform was initiated in the beginning of 1991 when the Land Law was approved by parliament. This law, and the rules for its implementation, specified the mechanisms for the liquidation of socialist type enterprises and the reallocation of agricultural land to individual owners. Land in Bulgaria was never nationalized; therefore, from a legal point of view, this land reform is actually an act of restitution. The ownership of land parcels was restored to previous owners, or their inheritors, in the real or comparable boundaries that existed before collectivization during the 1950s.

Agricultural reform carried out in Bulgaria during the 1990s had two elements: (1) dissolution of the socialist's type of agricultural enterprises; (2) land restitution. The land was returned to individuals (or their heirs) that owned the land before collectivization took place. Most of the landowners however were old and had several inheritors. This led to land subdivision and has resulted in a growing number of small privately owned subsistence and family farms which have to manage numerous fragmented small plots which are often some distance from the homestead.

Pre-collectivization land ownership in Bulgaria was highly fragmented and the restitution process deepened this problem even further. Landowners from 1950 had grown too old to farm, and some had passed away. In addition, many of them had several inheritors, now living in the towns, with little or no experience in agriculture and no ambition to return to the villages. Table 1 indicates changes in farm size and fragmentation between 1897 and 2001.

Table 1: Farm size and land fragmentation in Bulgaria (1897-2001) in hectares.

Indicators	1897	1908	1934	1946	2001
Agricultural land	3 977 557	4 625 787	4 368 429	4 317 696	4 182 000
Farm number	546 084	640 511	884 869	1 103 900	1 777 200
Plot number	7 980 000	9 880 000	11 862 158	12 200 000	8 007 000
Average farm size	7,3	6,3	4,9	3,9	2,4
Plot number per farm	9,98	10,58	13,4	11,0	4,5
Average plot size	0,498	0,468	0,368	0,354	0,522

Source: Annual Statistical Year Books of Bulgaria (1908-2001)

Notably, whilst the agricultural area has remained the same, there has been a substantial increase in the number of farms and a reduction in farm size.

Soon after the co-operatives were abolished, new producer co-operatives were established in almost all villages[2]. The opportunities for establishing private farms were constrained by traditions, land fragmentation and a lack of resources. Moreover, frequent changes in legislation and the decline of the food processing industry created high uncertainty and further hindered the development of stable production units.

The land restitution process was slow and contradictory. At the end of land reform in the year 2000, Bulgarian farm structure was dominated by three groups: small subsistent farms operated by people close to retirement, co-operatives, most of them in a bad financial situation, and large commercial farms. The number of middle-size family farms remained small, but growing.

Farmland fragmentation has two main aspects, fragmentation in ownership and use. Fragmentation of legal ownership refers to the number of holders of a single title, sharing equal real rights. As a rule, this type of fragmentation is a consequence of the process of recent land reform which has occurred throughout the country. Fragmentation in ownership is also present either when an individual or an economic unit owns several plots located in different places. This type of fragmentation is rather common in Bulgaria. In most cases, a potential lessee has to negotiate with many owners, which entails a lot of effort, time and money and creates uncertainty. Table 2 indicates land fragmentation in ownership across different regions of Bulgaria.

Table 2: Land fragmentation in ownership by regions, area given in hectares.

Regions	Number of parcels	Total area	Average size per parcel
North-West	1 015 481	688 496	0,678
North-Central	1 660 992	1 071 340	0,645
North-East	1 171 406	1 309 632	1,118
South-West	1 804 317	784 878	0,435
South-Central	2 729 201	1 260 891	0,462
South-East	866 418	739 055	0,853
Total	9 247 815	5 854 292	0,643

Source: Kasabov and Koritarova, 2004

Fragmentation in land use is present when a single farm enterprise cultivates several plots (regardless of whether owned or leased) located in different places. Fragmentation of this type can hamper the efficiency of management and production because plot sizes are small and this imposes constraints on cropping and use of technology. Land leasing is widely used to circumvent this problem and to consolidate land. Cropping arrangements which locate crops in parcels best suited to their production can also improve efficiency of agricultural production.

Fragmentation in ownership and land use differs among the regions of Bulgaria. Both types of fragmentation are less common in the North-east of the country. This area is specialized in grain production and in general plots are larger in size as indicated in Table 2 which shows an average plot size of 1.1 hectare.

In summary, fragmentation in ownership and land use is a consequence of factors such as crop structure, legislation, and traditions and in general farms are quite small in size.

From extensive observation and field research, we know that farmers take advantage of differences in land quality by selecting crop species and varieties best suited to the plots they have available. Soil types in Bulgaria are generally very fertile, but involve considerable variety. Often around one village there are several soil types that may differ significantly in quality. This is a prominent feature of villages in the south of the country where valley areas are known for their high soil fertility but mountainous areas are not.

Historically, (prior to 1944) a high level of self sufficiency was typical of the study area with an average rural family producing most of the food items they required. The spatial distribution of crops closely matched land productivity with forage crops being located in upland areas and more demanding intensive cash crops in valley bottoms around village centres. Land values and rents, at the time mirrored differences in land productivity. Each household owned several plots of varying quality which were spatially dispersed and had different uses. By growing a variety of crop types well suited to each individual plot’s agro-ecological conditions. In addition, peasant households retained seeds from their own production, which resulted in many distinct varieties and land races of local crop types which suited the region.

A number of notable changes to the cropping system took effect during the collectivization process (post 1945) whereby all village land was subsumed within cooperatives which eventually became (in 1971) large Agro-industrial Complexes (AIC). Traditional crops were replaced by high yielding varieties; decision making became progressively more centralised and each village specialized in a narrow range of crops. Seed production was confined to specialist farms, supply was centrally controlled, and only laboratory tested varieties could be used for production. Notably, decisions over the spatial location and precise mix of crops were no longer made by the household.

After the reforms of the early 1990s, the system of seed control collapsed. An unregulated wholesale market for seed quickly developed but these were often expensive and of poor quality. Presently local farmers can purchase their seed and agrochemicals from local agricultural stores which also offer a farm advisory service. Trust by households in farm advisory services and inputs is low due to the poor quality of information and products they offer. Consequently many of the small farmers use their own seeds despite the risk of disintegration which causes lower yields. Regrettably most of the traditionally grown (prior 1944), crop varieties which involved very little disintegration have disappeared.

Study sites, Sampling and Survey Description

The study is located in the Thracian lowlands along the Maritza River in the Plovdiv region of Bulgaria. The population numbers approximately half a million inhabitants of which about 68 thousand are engaged in agriculture. The region covers 170 thousand ha in total including 150 thousand ha of agricultural land. Annual precipitation at 520-570 mm (atmospheric humidity deficiency is 520 - 320 mm) is inadequate for many arable crops which require irrigation. Irrigated installations cover over 80% of the land, but approximately only 20 percent of this area is actually irrigated. The region includes more than ten different soil types, the most prevalent being alluvial-meadow soils (yellow), chernozem-smolnitza (black) and cinnamon-meadow soils (grey). The main crop types include fruit and vegetables which have a long association with the area, generate substantial revenue per unit of land and thus provide a comparatively good income for rural households.

Two independent techniques were used for data collection. First, we obtained information on the spatial nature and extent of land fragmentation from the Regional Agriculture and Forestry Office and the Department of Economics at The Agricultural University of Plovdiv. Second, we carried out a detailed on-site survey of middle size farm households in order to investigate inter-relationships between land fragmentation and crop biodiversity. In the spring and summer of 2005 a sample of 100 farms from 20 villages (3% of farms in the Plovdiv agricultural region) were identified as operating management regimes considered typical of the region. We used three steps in identifying the farms. The initial step involved the selection of several areas with different soil quality, crop specialization, and distance from the main market – the City of Plovdiv. During the second step we selected twenty typical villages within the chosen areas and the final step involved the random selection of five family farms in each village. The Farms selected generally provided sufficient income to keep at least two family members in agriculture and they varied with respect to fragmentation (number of parcels), level of biodiversity (species and crop varieties), farm specialisation, natural conditions (soil type) and size.

Personal interviews were undertaken by staff from the Agricultural University of Plovdiv with the owner-operator at the owner's property. Each interview lasted approximately one hour and followed a standard format. The questionnaire was piloted for one month during February 2005 and this aided in the design of the survey.

Each survey provided detailed data on revenue and cost summaries, farm premia, use of technology, labour and costs of farm operations, and arable and horticultural activities. The survey focused principally on detailed data acquisition of individual plot data. Spatial data on all plots were recorded including size, exact location and distance from other plots managed by the household. Other plot information included information on past plot management, property rights, input use, soil type, crop rotation, species and varieties grown, technology used, output and sales and the level of cooperation (with other farmers as well as local groups and cooperatives). Data on property rights, the formation of local tenurial and cooperative arrangements were of some interest given the process of land reform and the historical background of centrally run collectivization.

Production Processes and Land Fragmentation

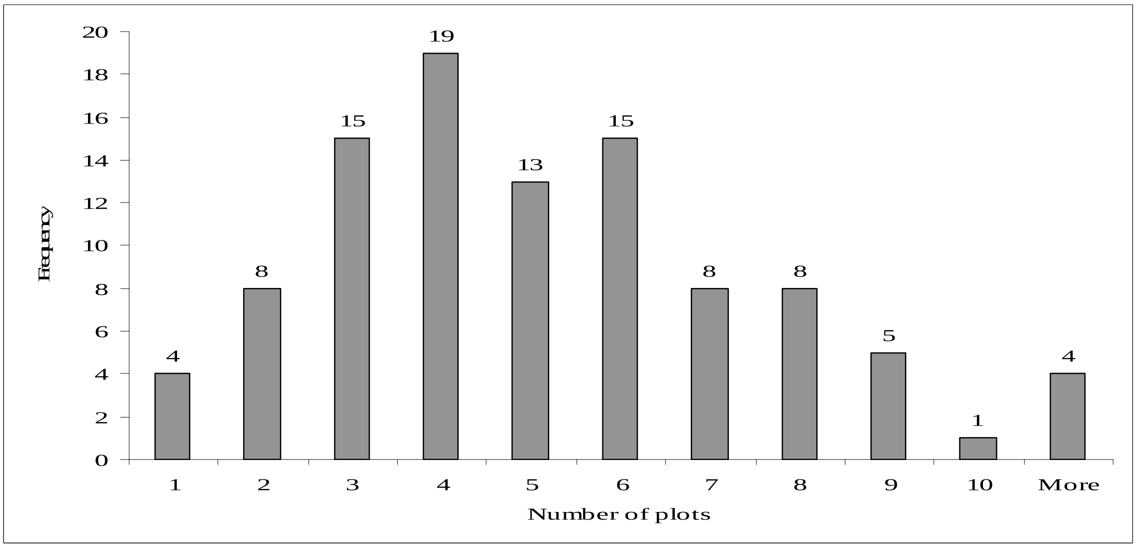
In what follows we provide some summary statistics (Table 3) and a description of the particular features of the farms in our sample data set, their property rights, land fragmentation, number size and spatial distribution of plots, agro-biodiversity and agronomic practices.

Table 3: Summary statistics

	Mean	Std Deviation	Min	Max
Farm Profitability	130.446	186.0246	4.24	1081.08
Farm crop diversity	1.70513	0.867764	0.16103	5.12821
Fragmentation	5.25	2.731688	1	16
Average plot size	15.2751	48.74242	1.17	420
Intensity of input use	132.662	134.2098	4.79	752.16
Experience	30.29	17.86724	4	70
Land quality	64.7141	9.693989	42.78	85
Distance	3.2	2.7	0.1	20
Labour	0.10934	0.1398336	0	0.75188

The average farm size is 6.5 ha[3] and Figure 1 indicates the distribution of farms according to size. The average number of plots per farm recorded is 5.25 (Table 3) with the number of plots per farm varying from to 1-16. Figure 1 presents the distribution of farms in the sample according to the plots they cultivate.

Figure 1. Distribution of the farms according to the number of plots they cultivate (*n = 100).*



Fifty-nine farms in the sample manage up to 5 plots. A possible reason for this is the abandonment of smaller plots because they are difficult to cultivate and irrigate.

Soil quality is an important factor that influences the productivity of individual plots[4]. Average soil quality for our sample is 64.7 (with plots varying between 43-85). With respect to plot location, our analysis indicates that cultivated plots are located at an average distance of 3.2 km from village centres. Plots are also situated at an average altitude of 238 m (range 170 – 500m) and they generally occurred on fairly flat land which makes them suitable for growing a wide range of crops. The proportion of irrigated land is high (43 %) but because of irregular water supply most of the respondents use pumps (72 % of the irrigation facility), thereby increasing production costs and exacerbating soil salinity. Most farms use gravity-fed type irrigation with only two farms using drip irrigation systems. Of all cultivated plots, 80% of the land is owned by the household, the remainder being rented.

In terms of the tenurial status and ownership, more than 80 % of the plots were acquired after 1998 during the course of recent agrarian reforms: two-thirds (66.7 %) of the cultivated plots are inherited, one-fifth (19.8 %) are rented and 9.1 % have been purchased.

Farm fragmentation which arises from land being subdivided amongst several family heirs can eventually lead to non-viable small holdings that cannot support a farm household. However, our findings indicate that farmers in our sample have resolved many of the legal problems associated with sub-dividing land amongst their heirs. We note that 71 % of the plots in our sample are owned by only one individual, 19 % - by two owners, approximately 5 % by three owners and a further 5 % by more than three owners. About 61% of the arrangements made to rent land are oral and the rent typically ranges from 80 to 600 levs per hectare (1 lev = 0,512 euro). Orchards and vineyards command the highest rents (450-600 levs/ha), with horticulture (300-350 levs/ha) and non-irrigated cereals yielding the lowest (80-120 levs/ha).

The level of agricultural experience can be expected to influence production and this ranges from four to nearly seventy years in terms of our sample (mean of 30 years). Results show that individuals performing management functions have about twenty-years of experience in the agricultural sector, which is considered a comparatively good level for the conditions of transition.

Crop rotations constitute an important agronomic practice with almost all farms consistently rotating crops grown within the plots (the average crop rotation equals 2.11 crops per plot per year). Typically two crops are rotated (on 78 % of plots) with four or five crops grown in rotation on 16 % of the plots. Rotation is not applied on 8 % of the plots, because these involve plantations of perennial crops. The intensity of land use differs between farms and plots with about 21 % of all plots yielding up to three crops per year. This practice is especially prevalent in smaller farms within villages in close proximity to Plovdiv city.

A key question posed by this study is concerned with the relationship between farm decision making, biodiversity and farm fragmentation. In this study, crop biodiversity is measured using the Margalef biodiversity index (for more details see Magurran 1988, Smale et al. 1998). This index is particularly well suited for situation when there is variation in the number of crops grown. [5] In recent years agrochemical usage is becoming more prevalent and very few plots exhibit nutrient deficiencies. The average inorganic fertilizer use (phosphates, nitrate and potassium) is 292,5 kg/ha and ranges from zero (non-irrigated plots) to 800 kg/ha (intensive glass-house production). Farms that specialise in vegetables, grapes and fruit also use organic manures applied every few years (average application rates of 1,652 kg/ha). Almost all farms use fungicides (97%) and insecticides (98%) and about 39% use herbicides whilst only 2% of farms used no pesticides at all. Alternative methods of pest control are also practiced on 61% of all plots. These include manual and mechanical weed control.

Production costs are influenced by farm size, use of own resources and production intensity and these costs vary from 160 to 87,600 levs per farm. The total and average costs are modest for labor-intensive semi-subsistence small family farms that use their own land, labor and capital. Costs increase substantially for market oriented specialist commercial enterprises reliant on non-family labour, rented land and bank credit. Average total costs for all farms amounts to 6,152.23 levs (946.50 levs/ha.).

Finally this section describes the socioeconomic characteristics of the households sampled. The households consist of an average of 4.3 individuals with an average age of 42.2 years (six years higher than that for the county). More than 39 % of the family members are secondary school educated. The distribution of work in the family is evidence of comparatively higher universality of labor. Most activities can be performed by household members and only a minority of farms required family members to have a specialist training. We note a general trend whereby household members are actively seeking or engaged in off-farm employment in order to supplement farm incomes. We now turn to to a short description of the empirical approach taken in our study.

Empirical Strategy

In the model described below, we aim to explain the impact of land fragmentation on farm profitability and on farm biodiversity with a two equation system. Given that biodiversity is itself affected by land fragmentation, potentially we have a recursive system characterized by simultaneity and endogeneity. We assume that farm profitability is affected, among other things, by crop biodiversity and fragmentation, thus:

$$\textbf{Farm Profitability} = \beta_0 + \beta_1 \textit{Biodiversity} + \beta_2 \textit{Fragmentation} + \beta_3 \textit{Inputs use} + \beta_4 \textit{labour} + \beta_5 \textit{Experience} + \beta_6 \textit{Land Quality} + \varepsilon_1 \quad (1)$$

The second equation identifies the role of fragmentation, and other determinants including the amount of crop biodiversity on a farm. Crop biodiversity is measured by the Margalef index. Farm biodiversity is given by land fragmentation, intensity of input use, land quality (represented by q) and a set of controls:

$$\textbf{Farm Biodiversity} = \alpha_0 + \alpha_1 \textit{ Fragmentation} + \alpha_2 \textit{ Inputs use} + \alpha_3 \textit{ Experience} + \alpha_4 \textit{Land quality} + \alpha_5 \textit{ Average plot size} + \alpha_6 \textit{ distance} + \varepsilon_2 \quad (2)$$

Firstly, we need to consider that in this situation the disturbances ε_1 and ε_2 are likely to be correlated. Initially we thus adopt a seemingly unrelated regression (SUR) system that is a structural approach that has contemporaneous cross-equation error correlation. A Breush-Pagan test for the independence of the error terms has also been performed.

However, by construction, the system of structural equations composed by (1) and (2) is recursive. Endogenous explanatory variables are the dependent variables from other equations in the system. Indeed, biodiversity is the dependent variable in equation (2) but also an explanatory variable simultaneously in (1). We first implemented a Durbin-Wu-Hausman test to test for endogeneity for the biodiversity index. We rejected the null hypothesis of exogeneity at 10% level. To handle endogeneity the estimation is addressed using a three-stage least squares approach (3SLS) which is presented below. This method uses all the exogenous variables in the system to build up a matrix of instruments. A definition of the key variables used in the empirical model is provided in Table 4. Finding suitable instruments can, notoriously, be a very difficult task in applied research. We identified as possible instruments average plot size and distance. The Sargan/Hansen test for overidentifying restriction was used. We failed to reject the null hypothesis. Therefore, the instruments appear to be uncorrelated with the disturbance process. The relevance of the instrument has been also tested via an Anderson canonical correlation procedure. We rejected the null hypothesis. Our instruments appear to be relevant.

Table 4: Definition of the variables

Variable name	Definition
Farm profitability	Net farm income levs per decare
Biodiversity	Margalev=(S-1)/ln(land)
Fragmentation	Number of plots
Intensity of input use	Number of treatments
Labour	Number
Experience in agriculture	Years of experience
Land quality	grade from 0-100
Distance	
Average plot size	In decares

Results

Table 5 reports the econometric results of the Three Stage Least Squares (3SLS) analysis which are shown in column (B). For consistency the Seemingly Unrelated Regression (SUR) results are given in column (A).

Table 5: Estimation results

Variables	**SUR (A)**		**3SLS (B)**	
	Coeffs	Std Errors	Coeffs	Std Errors
1- Dependent variable: Farm Profitability				
Farm biodiversity	-	-	62.028**	30
Fragmentation	-7.72**	3.91	-12.033***	4.43
Intensity of input use	1.08***	0.087	0.927***	0.11
Experience	1.04	0.63	0.11	0.83
Labor	122.95**	75.99	209.52***	80.075
Land quality	-2.31	1.69	-1.5	1.2
Constant	128.11*	68.033	-24.122	84.39
2 - Dependent variable: Farm crop diversity				
Fragmentation	0.053*	0.028	0.05*	0.02
Intensity of input use	0.0017***	0.00065	0.0016***	0.00063
Experience	0.0122***	0.004	0.0116***	0.00479
Land quality	-0.011	0.008	-0.0109	0.0078
Distance	-0.082***	0.027	-0.0823***	0.026
Average plot size	-0.0024**	0.0012	-0.0029***	0.001
Constant	1.81***	0.52	1.87***	0.51

N=100; Breush-Pagan test for independence: 1.836 [$chi^2(1)$, Pr =0.17]; Durbin-Wu-Hausman chi-sq test: 2.87054 Chi-sq(1) P-value = 0.09; Anderson canon. corr. likelihood ratio test for instruments relevance= 13.96 - P-value: 0.00093. Sargan statistic (overidentification test of all instruments): 0.018 Chi-sq(1) P-value = 0.89. Significance levels are denoted by one asterisk (*) at the 10 % level, two asterisks (**) at the 5 % level, three asterisks (***) at the 1 percent level. Robust standard errors have been used.

Close inspection of column (B) reveals that farm biodiversity is positively correlated with farm profitability. Thus our findings indicate that farms that grow a range of different products perform better, when compared to those that do not. This result is consistent with the findings reported in the existing literature (Smale et al., 1998; Widawsky and Rozelle, 1998; Di Falco and Perrings, 2005) and can be explained by the fact that there are economic benefits associated with crop diversification. Indeed, a variety of crop species can better match different agroecological conditions that occur within the plots. Moreover, different crop species can reduce the implication of price and production risk and allows farmers the option of marketing their produce several times throughout the year.

As column (B) in Table 5 shows land fragmentation, instead, plays a detrimental role on farm profitability. Farms with fragmented land are therefore less profitable. With respect to conventional inputs both the intensity of input use and family or household labour are both positively correlated with profitability. The estimated coefficient for the variable "family experience in farming" (denoted Experience in Table 5) is statistically not significant. Also, land quality is not statistically significant.

We now focus on the second equation which is used to analyze the relationship between crop biodiversity and land fragmentation. Table 5 indicates that land fragmentation is positively correlated with the number of crops. The estimated coefficient is, of course, very similar with the result from the SUR estimation and is always statistically significant. The estimated coefficient is, indeed, statistically significant at the 10% level. This result emphasizes the point that the widespread level of land fragmentation which has arisen as a consequence of land reform and institutional change in Bulgaria has increased both crop biodiversity and agro-biodiversity in the agro-ecosystem.

The intensity of input use is found to be positively correlated with the dependent variable. This is a different perspective to results on intra-specific crop biodiversity (Di Falco and Chavas, 2006). This positive correlation may be related to the particular crop types we studied. These consist mainly of different species of vegetables. Therefore increasing the portfolio of crops increases the requirement in terms of chemical use (fertilizer and pesticides). The quality of land is negatively related to crop diversity. This result is statistically significant only in the 3SLS regression. Therefore increasing land quality favors simplification of the agro-ecosystem. Experience in farming is positively and significantly correlated with farm biodiversity. Average plot size, instead, is negatively correlated to farm biodiversity. Thus, smaller plots encourage crop diversification. Distance is also negatively correlated with farm biodiversity.

Conclusions

This paper provides a conceptual framework for investigating the impact of land fragmentation on farm productivity and agro-biodiversity in the Plovdiv region of Bulgaria. First, our findings indicate that farm biodiversity is positively correlated with farm profitability. Our results show that farms that grow a wide range of different crops and varieties perform better, when compared to those that do not. This result is consistent with the findings reported in the existing literature (Di Falco and Perrings, 2005). These results can be explained by the fact that there are economic benefits associated with crop diversification. Indeed, a variety of crop species can better match different agroecological conditions that occur within the plots. Moreover, different crop species can reduce the implication of price and production risk and allows farmers the option of marketing their produce several times throughout the year.

Second, our results show that land fragmentation is detrimental to farm profitability. Farms with fragmented land are less profitable. This is probably due to inherent inefficiencies arising from the spatial distribution of land. Fragmented fields are problematic to cultivate, it is difficult to use machines; space is lost along field boundaries and there are problems with development and management of irrigation systems (Bently, 1987).

Third, we find that land fragmentation is positively correlated with the number of crops. Results from the Seemingly Unrelated Regression and Three Stages Least Squares both stress the point that land fragmentation in Bulgaria has increased both crop biodiversity and agro-biodiversity in the agro-ecosystem. Our econometric findings suggest that the impact of farm fragmentation is twofold. Firstly, fragmentation exerts a direct effect which is negative. Greater fragmentation reduces revenues. Secondly, the other indirect effect is positive. More fragmentation increases farm crop diversification, and this, in turn, has a positive effect on profitability. The reduction in revenues due to higher levels of land fragmentation, can thus be buffered by the positive role that fragmentation has on diversity.

Third, we note that the majority of farmers in our sample have resolved many of the legal problems associated with sub-dividing land amongst their heirs. Most of the plots in our sample are owned by only one individual, it was rare to find a situation where plots were owned by more than three owners.

Fourth, we note a general trend whereby household members are actively seeking or engaged in off-farm employment in order to supplement farm incomes.

Fifth, we observed that the intensity of input use is found to be positively correlated with crop diversity. This is contrary to results on intra-specific crop biodiversity (Di Falco and Chavas, 2006). It is possible that this positive correlation may be related to the particular crop types we studied. These consist mainly of different species of vegetables. Therefore increasing the portfolio of crops increases the requirement in terms of chemical use (fertilizer and pesticides). The quality of land is negatively related to crop diversity. This result is statistically significant only in the 3SLS regression. Therefore increasing land quality favors simplification of the agro-ecosystem.

The policy implications are important in terms of both the private and public good dimensions of crop diversity. At present there is a policy vaccum whereby the old system of seed control which was geared toward large commercial units has collapsed. Historically, (prior to 1944), peasant households kept seeds from their own production, which resulted in a wide variety of crop types which suited the region. Unfortunately, many of the traditionally grown crop varieties which involved very little disintegration have since disappeared. During collectivization traditional crops were replaced by high yielding varieties, each village specialized in a narrow range of crops and seed supply and quality was centrally controlled and monitored. The reforms of the early 1990s, lead to the collapse of the system of seed control, development of an unregulated seed market of inconsistent quality. Presently farmers in this study have control over the spatial location and precise mix of crops but many use their own seeds despite the risk of disintegration which causes lower yields. Policy makers need to put in place better systems of see quality and regulation that utilize local land races which can take advantage of local conditions such as farm fragmentation and small farm size. Careful consideration should policy makers need to carefully consider four important issues: 1) improving seed quality; 2) providing a wide range of crop types and varieties to farmers to enable them to exploit farm conditions; 3) land consolidation and improvement; 4) in situ crop diversity conservation. These four issues need an integrated policy and cannot be considered in isolation. A failure to do this could mean that measures that are aimed at reducing land fragmentation may undermine the positive role of crop biodiversity on farm profitability. Policies that aim to increase land consolidation and reduce fragmentation may overlook the positive link between diversity and plot heterogeneity. Policies that address the issue of land fragmentation on revenues should, therefore, consider the crucial role that this has on other variables such as farm biodiversity.

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[1] Agricultural biodiversity (or agrobiodiversity) is defined as a component of biodiversity, referring to all diversity within and among species found in crop and domesticated livestock systems, including wild relatives, interacting species of pollinators, pests, parasites, and other organisms (Qualset et al., 1995; Wood and Lenné, 1999).

[2] For a more detailed description and analysis of the land restitution process and the fate of the co-operatives, see Davidova et al. 1997.

[3] Ninety-two of the farms sampled range from 1-10 ha with an average farm size of 3.6 ha, which is close to the region's average for family farms.

[4] Soil quality is measured on a 100 point scale (100 = best soil type; 0 = worst soil type, not suitable for agricultural production).

[5] The Margalef index is a measure of richness of species. Indices of spatial diversity have, also, been proposed (Smale et al, 2003). The lack of information on the land allocation to different crop species prevented us to use this class of indices. A survey of different measures of crop biodiversity is provided by Meng et al., 1998.