Impacts of land fragmentation on the cost of producing wheat in the rain-fed region of northern Jordan

Amer S. Jabarin [a], Francis M. Epplin [b,*]

[a] Department of Agricultural Economics, University of Jordan, Amman, Jordan
[b] Department of Agricultural Economics, Oklahoma State University, Stillwater, Oklahoma 74078-0505, USA

Abstract

In some cultures inheritance customs results in land fragmentation such that over time operating farms become composed of a collection of spatially dispersed fields rather than a contiguous land unit. This study was conducted to determine the impact of land fragmentation as measured by average field size on the average cost of producing wheat in the rain-fed region of Northern Jordan. Primary data were collected from farmers in the region. Generalized Least Squares was used to estimate the average variable cost of producing wheat. It was determined that the average variable cost of producing wheat is a decreasing function of field size. Land fragmentation increases production costs. Continued land fragmentation will lead to decreasing efficiency and is problematic when it results in small fields.

1. Introduction

Small farm size and land fragmentation have been hypothesized to be impediments to economical wheat production in Jordan. They are believed to be a principal cause of Jordan's low productivity and major obstacles to the development of the rain-fed agricultural region (El-Hurani and Duwayri, 1986).

In some cultures the desire to leave each heir an equal portion of the farm leads farmers to divide each field in each generation (Binns, 1950).

Partial inheritance leads to ever-diminishing field size (Clout, 1972; Moore, 1972; Burton and King, 1983). Operating farms are often composed of a collection of spatially dispersed fields rather than a contiguous land unit.

Land fragmentation is defined as the division of a single farm into several separate, distinct parcels (Binns, 1950). Many developed and developing countries encounter a land fragmentation problem. Some consider land fragmentation to be a major impediment to efficient field crop production (Binns, 1950; Dovering, 1965; Grigg, 1983; Jacoby, 1971; Karouzis, 1971; King and Burton, 1982). Small and irregular fields increase the costs of moving workers and equipment and reduces the field efficiency of machines relative to that

* Corresponding author.

obtainable in large, rectangular fields (Buller and Bruning, 1979).

While there are costs associated with land fragmentation, under some circumstances spatial dispersion may be beneficial. An individual farmer who manages several dispersed parcels may exploit differences in elevation or soil type by scheduling plantings to reduce risk and distribute labor requirements over time (Bentley, 1987). In addition, fields in different zones may permit a farmer to produce a more diversified portfolio of crops (Cole and Wolf, 1974; Forbes, 1976; Friedl, 1974; Weinberg, 1972). In mountain regions, crops at lower elevations mature before those at higher elevations. A farm family may exploit differences in elevation to synchronize harvest with available family labor, reduce requirements for hired labor, and spread out fresh food supplies over time (Netting, 1972; Forbes, 1976; Friedl, 1974; Galt, 1979).

Land fragmentation may facilitate risk management through diversification even in relatively homogeneous environments such as that found in the Great Plains of the USA. For example, hail storms are often localized such that the probability of a total loss is less for a farmer with spatially dispersed land tracts. Similarly, rain from thunderstorms is often localized such that some fields may produce well in certain years, while others do well in other years (Carlyle, 1983; Heston and Kumar, 1983).

2. Land fragmentation in Jordan

One factor which influences land fragmentation in Jordan is the law which governs the partitioning of land into a single landholding. Outside the city or village limits, the minimum size of a landholding which can be divided into a separate holding is one hectare. However, the law permits for common ownership of one single piece of land (in some areas as small as one-tenth hectare). Common ownership is a routine consequence of inheritance under Islamic law or purchase. Land owned by an individual passes to heirs after death.

Available data indicate that the average farm size in the rain-fed regions of Jordan is 8 ha (Agricultural Statistics Indicator, 1988). However, most farms are composed of dispersed parcels. The average landholding is divided into 2.5 pieces such that the average contiguous field size in one location is 32 dunums (a dunum is one-tenth of a hectare).

Arabiat and Al-Kadi (1988), concluded that the degree of agricultural land fragmentation as measured by an index they developed, is very high in northern Jordan. Qasem (1985) has reported that land fragmentation is a continuous process. The number of individuals who acquired ownership rights increased every year from 1976 to 1981. The data in Table 1 show that in 1976, for example, 2657 individually owned land parcels changed ownership in Jordan. The ownership of

Table 1
Number of individually owned land parcels which changed ownership in Jordan (1976–1981) and number of individuals acquiring ownership

Year	Number of individually owned land parcels which changed ownership	Number of individuals acquiring ownership of the transferred land
1976	2 657	7 033
1977	2 445	8 313
1978	2 898	9 853
1979	3 028	10 295
1980	3 160	10 744
1981	3 480	11 832
Total	17 668	59 070

Source: Qasem, 1985.

these parcels was transferred to 7033 individuals. During the period from 1976 to 1981, a total of 17 668 individually owned parcels were transferred to 59 070 individuals. The number of owners of the transferred land almost tripled. These data do not address the issue of parcel dispersion for individual farmers. While the number of owners may have increased, data are not available to determine the change in the number of farmers over this time period.

Data are not available to directly measure the impact of decreasing parcel size on farm size or the size of fields farmed. For example, a single farmer may acquire the rights to farm a number of contiguous but independently owned parcels through various tenancy arrangements. However, for a given size of farm, the transactions costs of renting could be expected to be an increasing function of the number of landlords. For example, a farmer with 100 units of land and two landlords is likely to incur less transactions cost than a farmer with 100 units of land and twenty landlords. An underlying assumption of the analysis presented in this paper is that the average field size available for farming decreases as the number of individual land owners increases.

Arabiat and Al-Kadi (1988) have determined that land fragmentation is a serious problem in Jordan. The analysis presented by Qasem (1985) indicates that the degree of land fragmentation has increased. However, it remains to be determined if this fragmentation reduces economic efficiency or alternatively, if the benefits of fragmentation exceed the costs. No research has been conducted to measure the impact of fragmentation on production costs.

The objective of the research reported in this paper is to determine if field size influences production costs. One measure of economic efficiency is average per unit production costs. Hence, the specific objective is to estimate the average variable costs of producing wheat in the rain-fed region of Northern Jordan and to determine if land fragmentation as measured by average field size is beneficial, costly, or an insignificant factor.

The results are expected to be of use to those Jordanian farmers who have flexibility regarding field size. In addition, the results may be of value to those responsible for setting and modifying Jordanian public policies which influence land fragmentation.

3. Data and model

Primary data were collected by personal interviews of 63 farmers in the northern part of Jordan. The survey was conducted in July 1992 to obtain information regarding production practices. The area is relatively homogeneous. However, for the statistical analysis the farms were classified into one of three adjacent geographical regions. The regions differ slightly in elevation, soil, and expected precipitation.

Wheat enterprise cost and return budgets were prepared for each farm. The cost of land preparation, seed, seeding, fertilizer, combine or stationary thresher rental, hired harvest labor, and sacks were included as variable costs. Costs of land use, family labor, overhead and management were not obtained in the survey, and were not included as variable costs. The average variable cost of producing wheat was generated for each farm by dividing the total variable costs by yield and is expressed in terms of Jordanian dinar per kilogram (JD/kg) of wheat produced.

Some of the farmers reported that they used a traditional harvest method which requires the transfer of wheat shocks from the field to a stationary thresher for grain separation. Others reported that they hired a custom harvester who used a combine. All farmers who were surveyed and who reported the use of fertilizer indicated that they used ammonium sulfate. The fertilizer levels are expressed in kg of fertilizer used per dunum. Wheat grain yield is expressed in kg per dunum.

To determine if field size influences production costs, the estimated average variable cost is fitted as a function of the production region, fertilizer applied, harvest method, land seeded to wheat on the farm, and average wheat field size. The full model is represented in Eq. 1. The primary purpose of the model is to determine if production efficiency as measured by the average

variable cost of producing wheat is influenced by field size:

$$\text{AVC}_i = F(\text{R1}_i, \text{R2}_i, \text{FERT}_i, \text{HARV}_i, \text{SIZE}_i, \text{AFS}_i) \quad (1)$$

where AVC_i represents cost of land preparation, seed, seeding, fertilizer, combine rental, thresher rental, hired harvest labor, and sacks per kilogram of wheat produced (JD/kg); $\text{R1}_i = 1$ if farm i is located in production region one and 0 otherwise; $\text{R2}_i = 1$ if farm i is located in production region two and 0 otherwise; FERT_i is fertilizer level in kg per dunum used on farm i; $\text{HARV}_i = 1$ if the wheat on farm i was harvested with a combine and 0 if harvested with a stationary thresher; SIZE_i is land area (dunums) seeded to wheat on farm i; and AFS_i average field size (dunums) on farm i.

4. Statistical method

The Glejser test confirmed the presence of heteroskedasticity which is a common problem with cross-sectional data (Kennedy, 1989; Berndt, 1991; Judge et al., 1985; Salvatore, 1982). Heteroskedasticity is the term used to describe the violation of the ordinary least squares assumption that all the disturbance (error) terms have the same variance. In these instances ordinary least squares generates inefficient estimates of the standard errors and thus incorrect statistical tests.

Because of the presence of heteroskedasticity, Estimated Generalized Least Squares (EGLS)

(Judge et al., 1985) was used to estimate the model. A three-step procedure was used to obtain the EGLS estimates. In the first step, ordinary least squares was used to fit the model. The absolute values of the ordinary least squares residuals from the first step were regressed on the independent variables of the full model. The predicted residuals obtained from the second step were squared and their reciprocals were used to weight the original variables. The weighted average variable cost values were regressed on the weighted independent variables to obtain the EGLS parameter estimates.

5. Results

Statistical results are presented in Table 2. The first model includes two regional dummy variables, the dummy variable for harvest method, and continuous variables for fertilizer, land seeded to wheat, and average field size. Based upon the t-tests, the use of fertilizer decreases the average variable cost of producing wheat. The use of a combine also decreases average variable cost. The estimated coefficient for the land seeded to wheat on the farm variable is not statistically significant. However, the average field size variable is significant.

The variable for farm size (land seeded to wheat) was dropped and Model 2 was estimated. All parameter estimates in Model 2 are significant at the 1% level except for the intercept

Table 2
Statistical estimates of the average variable cost of producing wheat in Northern Jordan [a]

Variable	Model 1	Model 2
Intercept	0.196 (14.75) [b]	0.197 (14.99)
Region 1	−0.018 (1.08)	−0.026 (2.08)
Region 2	0.00003 (0.003)	0.0003 (0.032)
Fertilizer applied (kg/dunum)	−0.0034 (3.54)	−0.0033 (3.52)
Combine harvester	−0.0913 (10.09)	−0.0919 (10.35)
Land seeded to wheat	−0.00006 (0.80)	
Average size of wheat field	−0.00051 (2.08)	−0.00065 (3.43)
F	24.1	35.6

[a] The dependent variable is the average variable cost of producing a kilogram of wheat.
[b] The values in parentheses are t-statistics (absolute value).

Table 3
Estimated average variable cost of producing wheat in Jordan (dinar/kg) for selected average field sizes [a]

Field size (dunums)	Fertilizer level (kg/dunum)	
	0.0	10.3
10	0.182	0.148
20	0.175	0.141
30	0.169	0.135

[a] Predicted values derived from Model 2.

shifting dummy variable for region 2. The F-statistics for both models are also significant at the 1% level. The results indicate that fertilization, harvest method, and average field size significantly influence the variable cost of producing a kilogram of wheat.

The model confirms the hypothesis that average variable cost is a decreasing function of average field size. Average variable cost of producing wheat on the farms included in the survey is greater with small fields. That is, land fragmentation is an economically important issue.

Table 3 includes estimates of the AVC of producing wheat for three alternative field sizes based on parameter estimates of Model 2. As the field size increases the average variable cost decreases. A further decrease in the average variable cost resulted when as the fertilizer level was increased from zero to 10.3 kg/dunum which was the average level of fertilizer applied by those farmers who used fertilizer. For a given field size (AFS), say 20 dunums, the AVC decreases from JD 0.175 to JD 0.141, when the fertilizer level increases from 0.0 kg/dunum to 10.3 kg/dunum. In other words the AVC curve shifts up, indicating an increase in the AVC when the field size decreases.

6. Conclusions

Upon death of the owner, it is common for agricultural land in the rain-fed region of northern Jordan to be divided among heirs. Over time

the size of an average land holding has decreased. This process of land fragmentation has been cited as a major impediment to efficient production of field crops. However, the consequences of land fragmentation on the cost of producing wheat in Jordan has not been determined.

The objective of the research reported in this paper was to determine if field size influences production costs. The specific objective was to determine if land fragmentation as measured by average size of wheat fields is beneficial, costly, or an insignificant factor. Primary data were obtained from a sample of 63 Jordanian farmers. Estimated Generalized Least Squares was used to derive parameter estimates. Land fragmentation as reflected in average field size was found to be significant. The average variable costs of producing a kilogram of wheat in the region increases as the average field size decreases.

The modelling effort leads to several implications. Land fragmentation is indeed an impediment to efficient wheat production in the region. Clearly, within relatively large families, if land division among heirs is continued over several generations, at some point, fields would become so small that they could not be farmed. Individual farmers may have limited options to increase average field size and thus reduce average variable cost of production. However, if the land market is fluid, as the average field size decreases and the cost of production increases, there is an incentive for an entrepreneur to acquire and combine small adjacent plots into larger more efficient fields. The question remains as to what type of public policies may be put into place to reduce the degree of land fragmentation or to mitigate the cost imposed by land fragmentation. If the land market in the region is well developed, there may be some possibility for individual farmers to increase average field size by acquiring the rights to farm contiguous units. The transactions costs of working with numerous landlords has not been addressed. It is not clear if government policy can contribute to this process. However, it is clear that continued land fragmentation, will lead to decreasing efficiency and is problematic when it results in small fields.

Acknowledgements

References

Agricultural Statistics Indicators, 1988. Publication, Government of Jordan, Amman.

Arabiat, S. and Al-Kadi, A., 1988. The socio-economic segment of the regional project for rain-fed agricultural systems in Jordan. Arab Center for Research in the Dry Lands, Amman.

Bentley, J.W., 1987. Economic and ecological approaches to land fragmentation. In: Defense of a Much-Maligned Phenomenon. Annu. Rev. Anthropol., 16: 31–67.

Berndt, E.R., 1991. The Practice of Econometrics: Classic and Contemporary. Addison-Wesley, New York.

Binns, B.O., 1950. The consolidation of fragmented agricultural holdings. FAO Agric. Stud. 11, UN Food and Agriculture Organization, Washington, DC.

Buller, O. and Bruning, G., 1979. Management effects of spatially dispersed land tracts: a simulation analysis. West. J. Agric. Econ., 4: 129–142.

Burton, S. and King, R., 1983. Land fragmentation and consolidation in Cyprus. Agric. Admin., 11: 183–200.

Carlyle, W.J., 1983. Fragmentation and consolidation in Manitoba. Can. Geogr., 27:17–34.

Clout, J.D., 1972. Rural Geography. Pergamon, Oxford.

Cole, J.W. and Wolf, E.R., 1974. The Hidden Frontier: Ecology and Ethnicity in an Alpine Village. Academic Press, New York.

Dovering, F., 1965. Land, and Labour in Europe in the Twentieth Century (3rd Edition). Nijhoff, The Hague, The Netherlands.

El-Hurani, M. and Duwayri, M., 1986. Agricultural policy in Jordan – Policies affecting field crop production in the rain-fed sector. Abdul Hameed Shoman Foundation, Amman.

Forbes, J., 1976. We have a little of everything: the ecological basis of some agricultural practices in Methana, Trizinia. In: M. Dimen and E. Friedl (Editors) Regional Variation in Modern Greece and Cyprus: Towards a Prospective on the Ethnography of Greece. Annals of the New York Academy Science, New York.

Friedl, J., 1974. Kippel: A Changing Village in the Alps. Holt, Rinehart and Winston, New York.

Galt, A.H., 1979. Exploring the cultural ecology of field fragmentation and scattering in the island of Pantellaria. J. Anthropol. Res., 35: 93–108.

Grigg, D., 1983. Agricultural geography. Prog. Human Geogr., 7: 255–260.

Heston, A. and Kumar, D., 1983. The persistence of land fragmentation in peasant agriculture: an analysis of South Asian cases. Explan. Econ. Hist., 20: 199–220.

Jacoby, E.H., 1971. Man and Land. Andre Deutsch, London.

Judge, G., Hill, R., Griffiths, W., Lutkepohl, H. and Lee, T., 1985. Introduction to the Theory and Practice of Econometrics (2nd Edition). Wiley, New York.

Karouzis, G., 1971. Time wasted and distance travelled by the average Cypriot farmer in order to visit his scattered and fragmented agricultural holdings. Geogr. Chron., 1: 39–58.

Kennedy, P., 1989. A Guide to Econometrics. MIT Press, Cambridge, MA.

King, R.L. and Burton, S.P., 1982. Land fragmentation, a fundamental rural spatial problem. Prog. Human Geogr., 6: 475–494.

Moore, W.E., 1972. Economic Demography of Eastern and Southern Europe. Arno Press, New York.

Netting, R.McC., 1972. Of men and meadows: strategies of Alpine land use. Anthropol. Q., 45: 145–157.

Qasem, S., 1985. Agricultural policy formulation and administration in the agricultural section of Jordan. Ithaca Press, London.

Salvatore, D., 1982. Theory and Problems of Statistics and Econometrics. McGraw-Hill, New York.

Weinberg, D., 1972. Cutting the pie in the Swiss Alps. Anthropol. Q., 45: 125–131.