CHAPTER 6

EMPIRICAL ANALYSIS OF RESOURCE USE EFFICIENCY AND PRODUCTIVITY OF ALTERNATIVE CROPPING SYSTEMS IN EASTERN ETHIOPIA

6.1 Introduction

In eastern Ethiopia, smallholder farmers respond to the increasing pressure on land and the risks associated with drought and pest infestation by adopting a variety of cropping systems and management practices. These systems evolved over time depending on changing circumstances including population pressure, agro-climatic changes, and new agricultural technologies (Storck et al., 1991). For instance, it has been observed that improved maize and sorghum are intercropped with both annual and perennial cash crops (Bezabih, 2000). Cropping patterns such as sole and intercropping of annual crops and intercropping of annual and perennial crops are practiced by farmers to varying degrees of complexity as part of the their strategy to cope with dwindling land resources, pest and disease problems, and risks of crop failure.

Variations in these cropping systems and practices are observed at the farm as well as at plot levels. Whilst several socio-economic and institutional factors that affect farm level performance can be observed and analyzed at the farm level, that is not the case with plot-level management practices and cropping systems, which are so complex even within one farm with several fragmented plots (Storck et al., 1997). Many agronomic practices are measurable only at plot-level and the identification of the management practices, which are believed to explain much of the resource use efficiency gap is possible only through productivity analysis of cropping systems.

Current research efforts both in Ethiopia and elsewhere fail to consider variations in cropping systems and management practices at plot level in conducting efficiency analysis, thereby investigating only the very general (at best at farm level) social and economic factors impeding efficient production in agriculture. Consequently, the influence of farm management practices that are observable only at plot level on resource use efficiency largely remains unexplained. This study compares the resource use efficiency of alternative cropping systems and technologies in both the dry land and the wet highland zones using interspatial total factor productivity analysis.

6.2 Cropping Systems and Land Use in the Study Area

Adoption of alternative cropping systems by farmers in the study area is mainly dictated by land availability and the objectives of the farm household (Storck et al., 1991; Bezabih, 2000). Farmers' choice of the types of crops and cropping systems involve complex decisions. The decision of what combination of cash and food crops to produce depends on land availability, primacy of food self-sufficiency, and the managerial skills of the farmers (Storck et al., 1997; Bezabih, 2000). Farmers' choice of a cropping system involves the following decisions: 1) What food to produce for own consumption? 2) What land area is needed to produce enough food for the family? 3) How to partition available land to produce other crops for some cash income either in sole or intercropped systems? 4) Which cash crops to produce? 5) How to allocate available land, labor and other farm resources between seasons for satisfaction of the household subsistence needs and generation of a surplus to trade for cash? This complex decision process also involves managing a risk factor given the unreliable weather conditions under which farmers operate. Farmers with different land endowments face different constraints on their choice of a suitable cropping system. To capture the influence of differing land constraints and other factors on farmers' choices of types of crops and cropping systems the sampled households were classified into small, medium, and large farms. Land constraints are more critical in Meta, the wet highland zone, than in Babile, the dry land zone although available land is generally continually declining and scarce resource in both areas.

Accordingly, a wide range of crops and cropping systems are adopted in the two districts reflecting farmers' strategy to minimize crop failure, intensify production in face of the increasing pressure on land, and overcome the increasing losses due to crop pests and diseases, among others. The most widely grown cereal in Babile is sorghum whereas maize is the leading cereal in Meta. The fact that maize and sorghum are the main food staples in the respective districts reflects the influence of the crop suitability factor as sorghum is more adapted to the marginal conditions of Babile while maize suits better the high potential lands of Meta. The two crops are grown both as sole crops and intercrops in a variety of combinations with other crops (see Tables 6.1 and 6.2).

Farmers with smaller land areas in Babile tend to resort to more intercropping (43.8 percent and 37.5 percent in combinations of beans, sorghum and maize) than medium and large farms

(Table 6.1). On the other hand, sole cropping tends to increase with farm size for all types of sorghum and maize (local and improved). This reflects the need to intercrop on smaller farms as less land is available for sole cropping. Farm size also influences the choice of production technology as more medium and large farms use improved sorghum and maize seeds while all small size farms use local land races. Availability of land also determines how much area to use for cash crops, which significantly increases with farm size (see, for instance, groundnuts and khat, the main cash crops in the area, in Table 6.1).

Table 6.1: Percentage of farmers practicing major cropping systems in Babile

Cropping system	Small farms (< 1 ha)	Medium farms (>=1ha <=2 ha)	Large farms (>2 ha)	All farms
Groundnut/Local sorghum	6.3	3.3	-	3
Khat	31.3	62.3	82.6	62
Local Maize/Local sorghum	37.5	18	17.4	21
Haricot beans/Improved maize	-	4.9	21.7	8
Groundnut	37.5	95.1	95.7	86
Local sorghum	31.3	62.3	78.2	61
Khat/Groundnut	6.3	1.6	8.7	4
Local/Local sorghum	-	6.6	34.8	12
Local maize	12.5	19.7	26.1	20
Improved maize	-	14.8	56.5	22
Khat/local maize	6.3	4.9	4.3	5
Improved sorghum	-	3.3	17.4	6
Local/Local maize/Local sorghum	43.8	10.2	17.4	16
Local/local maize	6.3	3.3	-	3
Improved maize/local sorghum	-	1.6	4.3	2
Improved/Improved maize/Local sorghum	-	1.6	4.3	2

Source: Own survey.

As mentioned earlier, being the food staple, maize is grown by all farmers in Meta either as sole or intercropped (Table 6.2). Like in the case of Babile, more medium and large farms use improved seed than small farms, which may simply be explained by the financial inability of small farmers to purchase seed and hence tend to use their own. Nevertheless, significant proportions of the medium and large farms continue to use local maize varieties, possibly for their non-yield traits (taste, color, etc). The most intercropped system is maize-potatoes with larger percentage of small farmers (35.3 percent) intercropping compared to medium (23.5 percent) and large farms (6.7 percent), again confirming the influence of land availability on the choice between sole crops and intercrops.

Due to the bimodal nature of the rainfall in Meta, farmers grow barley and potatoes during the short rainy season and other crops during the long rainy season. Potatoes are also intercropped with other cereals during the long rainy season. Almost all sample farmers in Meta produced Irish potatoes either sole cropped during the short rains or intercropped with other annuals during the long rains. Irish potatoes are produced either for sale or for own consumption during critical times of food shortages in the wet highland zone. As large farmers can afford to allocate land to barley and potatoes during the short rains beginning February/March, once maize has been planted during that period, most of them grow barley (60 percent) and potatoes (53.3 percent) as sole crops that release land for wheat and beans to be planted during the long rains beginning June/July, once more confirming the importance of land availability in determining the choice of cropping systems.

Table 6.2: Percentage of farmers practicing major cropping systems in Meta

Cropping system	Small farms (< 0.5 ha)	Medium farms (>=0.5ha <1 ha)	Large farms (>=1 ha)	All farms
Khat	2.9	7.8	6.7	6
Local Maize/ Local Sorghum	11.8	13.7	13.3	13
Local sorghum	-	5.9	20	6
Local maize	32.4	41.2	66.7	42
Improved maize	26.5	33.3	53.3	34
Khat/local maize	-	11.8	13.3	8
Local/Local maize/Local sorghum	-	3.9	6.7	3
Barley	29.4	31.4	60	35
Tef	-	9.8	26.7	9
Potatoes	5.9	13.7	53.3	17
Beans	17.6	11.8	20	15
Wheat	8.8	23.5	33.3	20
Improved maize/Potatoes	5.9	13.7	6.7	10
Khat/Local maize/Potatoes	8.8	11.8	13.3	11
Local Maize/Potatoes	35.3	23.5	6.7	25

Source: Own survey.

6.3 The Analytical Framework

Partial productivity measures such as yield per hectare (land productivity) or output per person (labor productivity) are applied in most productivity analyses. However, such productivity measures can be misleading if considerable input substitution occurs as a result of widely differing input prices due to market imperfections. Although partial productivity measures provide insights into the efficiency of a single input in the production process, they mask many of the factors accounting for observed productivity differentials. A conceptually superior way of estimating productivity, and thus resource use efficiency, is to measure total factor productivity (TFP) defined as the ratio of aggregate outputs to aggregate inputs used in the agricultural production process.

There are two basic approaches to the measurement of productivity: the growth accounting approach, which is based on index numbers, and the parametric approach, which is based on an econometric estimation of the production, cost, or profit functions. In this paper we use the index number approach for three reasons. First, with the index number approach, detailed data on many input and output categories can be used regardless of the number of observations over time, which implies less problems with degrees of freedom or statistical reliability in working with small samples. Second, there is no need to aggregate outputs into a single index, thus avoiding input-output separability assumptions. Finally, under certain technical and market conditions, the econometric and index number approaches are equivalent. Advances in growth accounting theory have shown that non-parametric methods do indeed impose an implicit structure on the aggregate production technology (Diewert, 1976; Denny and Fuss, 1983).

The major difficulty with the index number approach is to derive the aggregate output and input measures that represent the numerous inputs and outputs involved in most production processes. Earlier approaches to TFP measurement used a Laspeyres or a Paasch weighting system where base period prices were used as aggregation weights. However, the Laspeyres and Paasch indexing procedures are inexact except when the production function is linear and all inputs are perfect substitutes in the relevant range (Christensen, 1975; Diewert, 1976). The most popular indexing procedure is the Divisia index, which is exact for the homogenous translog aggregator functions (Capalbo and Antle, 1988). The translog function does not require that inputs be perfect substitutes, but rather permits all marginal productivities to adjust proportionally to changing prices. Hence the prices from both production systems being compared enter the Divisia index to represent the differing marginal productivities. There have been relatively few applications of this in the context of cropping systems. Ehui and Spencer (1993) used an interspatial and intertemporal TFP to measure the sustainability and economic viability of alternative farming systems in Nigeria. Gavian and Ehui (1999) used an interspatial TFP to measure the production efficiency of alternative land tenure contracts in the Arsi area of Ethiopia.

This study analyzes the interspatial TFP, land productivity, and factor intensities of alternative cropping systems and technologies in eastern Ethiopia. The study adapts the methodology of Denny and Fuss (1983) proposed for measuring the intertemporal and interspatial TFP and that of Caves, Christensen, and Diewert (1982) proposed for a productivity comparison of several production units. Assume that the agricultural production process in land held under cropping system j can be represented by the production function

$$Y_j = Y(X_{nj}, D_j)\,, \tag{6.1}$$

where Y_j is the output level of cropping system j, j=1,2,..., J. X_{nj} is a vector of factor inputs n for cropping system j, and D_j is a vector of dummy variables for every cropping system other than the reference base cropping system which, in a multilateral setting, is not fixed and rather changes whilst deriving the TFP measure for a given system with respect to every other system. D_j denotes also the interspatial efficiency difference indicators. Equation (6.1) assumes that the production function in each cropping system has common elements as well as differences resulting from the cropping pattern maintained by the additional argument D_j. Suppose that we wanted to know the difference between the level of output on land held under cropping system j and on land held under cropping system k. Diewert's (Diewert, 1976) Quadratic Lemma is useful for the transformation of the production function for comparisons of several production units at a given time. Diewert's Quadratic Lemma basically states that if a function is quadratic, the difference between the function's values evaluated at two points is equal to the average of the gradient of the function evaluated at both points multiplied by the difference between the points $F(Z^1)-F(Z^0)=\frac{1}{2}\left[F(Z^1)+F(Z^0)\right]^r(Z^1-Z^0)$, where $F(Z^r)$ is the gradient vector of F evaluated at Z^r, $r=0,1$. Application of Diewert's Quadratic Lemma to a logarithmic approximation of equation (6.1), in a multilateral setting, gives

$$\begin{aligned}
\Delta \ln Y &= \left[\left(\ln Y_j - \overline{\ln Y}\right) - \left(\ln Y_k - \overline{\ln Y}\right)\right] \\
&= \frac{1}{2}\sum_n \left[\left(\left.\frac{\partial \ln Y}{\partial \ln X_n}\right|_{X_n = X_{nj}} + \overline{\left(\frac{\partial \ln Y}{\partial \ln X_n}\right)}\right)\right]\left(\ln X_n\big|_{X_n=X_{nj}} - \overline{(\ln X_n)}\right) \\
&- \frac{1}{2}\sum_n \left[\left(\left.\frac{\partial \ln Y}{\partial \ln X_n}\right|_{X_n = X_{nk}} + \overline{\left(\frac{\partial \ln Y}{\partial \ln X_n}\right)}\right)\right]\left(\ln X_n\big|_{X_n=X_{nk}} - \overline{(\ln X_n)}\right) \\
&+ \frac{1}{2}\left[\left.\frac{\partial \ln Y}{\partial D_j}\right|_j + \left.\frac{\partial \ln Y}{\partial D_j}\right|_k\right]\left(D_j - D_k\right),
\end{aligned} \tag{6.2}$$

where the interspatial or cropping system effect is defined as

$$\eta_{jk} = \frac{1}{2}\left[\frac{\partial \ln Y}{\partial D_j}\bigg|_j + \frac{\partial \ln Y}{\partial D_j}\bigg|_k \right](D_j - D_k). \tag{6.3}$$

Constant returns to scale and perfect competition in the input and product markets imply that $\left(\frac{\partial \ln Y}{\partial \ln X_n}\right) = s_n$, where the term s_n represents the cost share for the n^{th} input.

Using these assumptions, we can rewrite equation (6.2) as

$$\begin{aligned} \Delta \ln Y = & \frac{1}{2}\sum_n \left[\left(s_{nj} + \overline{s_n}\right)\right]\left(\ln X_n\big|_{X_n = X_{nj}} - \overline{(\ln X_n)}\right) \\ & - \frac{1}{2}\sum_n \left[\left(s_{nk} + \overline{s_n}\right)\right]\left(\ln X_n\big|_{X_n = X_{nk}} - \overline{(\ln X_n)}\right) \\ & + \eta_{jk} \end{aligned} \tag{6.4}$$

From equation (6.4) the output differential across cropping systems may be broken down into an input effect and a cropping system effect. Let A denote the land input so that equation (6.4) can be rewritten as

$$\begin{aligned} \Delta \ln\left(\frac{Y}{A}\right) = & \frac{1}{2}\sum_n \left[\left(s_{nj} + \overline{s_n}\right)\right]\left(\ln\left(\frac{X_n}{A}\right)\bigg|_{X_n = X_{nj}} - \overline{\left(\ln\left(\frac{X_n}{A}\right)\right)} \right) \\ & - \frac{1}{2}\sum_n \left[\left(s_{nk} + \overline{s_n}\right)\right]\left(\ln\left(\frac{X_n}{A}\right)\bigg|_{X_n = X_{nk}} - \overline{\left(\ln\left(\frac{X_n}{A}\right)\right)} \right) \\ & + \eta_{jk}, \end{aligned} \tag{6.5}$$

where $\Delta \ln\left(\frac{Y}{A}\right)$ denotes the change in land productivity levels. The first expression on the right hand side of equation (6.5) denotes the weighted sum of differences in factor intensities. Let's define this expression as

$$\psi_{jk} = \frac{1}{2}\sum_n \left[\left(s_{nj} + \overline{s}_n\right)\right]\left(\ln\left(\frac{X_n}{A}\right)\Big|_{X_n = X_{nj}} - \overline{\left(\ln\left(\frac{X_n}{A}\right)\right)}\right)$$

$$-\frac{1}{2}\sum_n \left[\left(s_{nk} + \overline{s}_n\right)\right]\left(\ln\left(\frac{X_n}{A}\right)\Big|_{X_n = X_{nk}} - \overline{\left(\ln\left(\frac{X_n}{A}\right)\right)}\right) \qquad (6.6)$$

The difference in land productivity can therefore be decomposed into two effects: (i) a factor intensity effect ψ_{jk} and (ii) a cropping system effect η_{jk}. If we want to measure the resource use efficiency levels across cropping systems, we rearrange the terms to isolate the cropping system effect as

$$\eta_{jk} = \left[\left(\ln\left(\frac{Y_j}{A}\right) - \overline{\ln\left(\frac{Y}{A}\right)}\right) - \left(\ln\left(\frac{Y_k}{A}\right) - \overline{\ln\left(\frac{Y}{A}\right)}\right)\right]$$

$$-\frac{1}{2}\sum_n \left[\left(s_{nj} + \overline{s}_n\right)\right]\left(\ln\left(\frac{X_n}{A}\right)\Big|_{X_n = X_{nj}} - \overline{\left(\ln\left(\frac{X_n}{A}\right)\right)}\right) \qquad (6.1)$$

$$-\frac{1}{2}\sum_n \left[\left(s_{nk} + \overline{s}_n\right)\right]\left(\ln\left(\frac{X_n}{A}\right)\Big|_{X_n = X_{nk}} - \overline{\left(\ln\left(\frac{X_n}{A}\right)\right)}\right).$$

The expression η_{jk} is the Tornqvist-Theil approximation (Capalbo and Antle, 1988) to the change in productivity levels due to the type of cropping system. The difference in the TFP of two systems is a function of the differences in land productivities and factor intensities. Factor intensities are the weighted sum of differences in the levels of the variable inputs applied per unit of land. Equation (6.1) indicates that there are two components that contribute to any observed differences in TFP. First are the changes in the level of land productivity. This is the major component underlying TFP differences. Second are changes in factor intensities. TFP is therefore the residual, or the portion of the change in output levels that is not explicitly explained by changes in input levels. However, increases in factor intensities may occur without any increase in TFP. Changes in TFP levels and factor intensities are not independent but they are of different significance. Increases in TFP will occur if land productivity increases proportionally more than the increases in factor intensity levels. But increases in land productivity that are due to increases in factor intensities are qualitatively (although not quantitatively) less significant than changes in TFP. Indeed land productivity will increase if a farmer applies more purchased inputs. Unless there are improvements in the use of these inputs, this will be a change in factor intensity and not TFP. It is clear that with TFP changes, in contrast with factor intensity differentials, the farmers' capability to produce more with the same resources has improved.

6.4 Data and Empirical Procedures

As clearly described in Chapter 4, data were collected from the 200 sample households through frequent visits to their crop fields to take plot-level measurements and observations throughout the 2001/2002 cropping season. The sampled households operated a total of 960 plots: 477 plots in Babile and 483 plots in Meta, where a plot was defined as a distinct management unit due to the farmer's choice to plant a unique crop or an intercrop on it. Input data were collected on a fortnight basis by asking the farmer to recall his/her activities on that particular plot during the past two weeks. Data included the quantities of seed and fertilizer used, labor time disaggregated by source, gender, age, and field operation and other miscellaneous inputs. The prices of all purchased inputs were also collected during this time. Output data on all the quantities of cereals, pulses, and oil crops harvested from each plot were recorded. A separate survey was conducted to collect output price information from Muti, Chelenko and Babile markets during planting and harvesting times of the major crops. Moreover, area measurements were taken in square meters from each plot with assistance from the farmers themselves and these were later converted to hectares.

For the purposes of this analysis, the different types of cropping systems were hypothesized to have different effects on the structure of production in the two agro-climatic zones in eastern Ethiopia. Given that the various cropping systems had multiple and dissimilar crop outputs and inputs, it was necessary to aggregate the varying inputs and outputs into meaningful categories. All crop outputs in each cropping system were aggregated into a single output index except in the case of sole cropped systems where the quantity of output in kg was considered. An implicit output quantity index was derived by deflating the value of all crops from a given cropping system by the weighted price index of crop outputs, the weights being the share of each crop output in total revenue. Inputs were aggregated into four categories: Labor, Oxen, Fertilizer (manure, DAP, UREA), and Seed. The indices of fertilizer and seed (for intercropped systems) were derived by deflating the value of all inputs in a given category by the weighted price index of inputs using the cost shares of each input involved as weights.

The markets for labor and oxen are, however, thin in the study area and may pose a problem of aggregation if one has to rely on observed wages for human labor and observed rents for oxen. Nevertheless, most of the sample farmers in the study area actually faced shortage of oxen and human labor but got assistance through the well-established tradition of labor- and oxen-exchange arrangements in their villages except that they had to actually provide adequate meals and khat with *hodja* (i.e., boiled coffee with or without milk*)* for the exchange labor (or *guza*) and feed for the exchange oxen. These were the actual costs facing sample farmers and their estimates obtained from the farmers were used as prices in this study. The prices used for the rest of the fertilizer and seed inputs were those obtained during the survey at planting time while output prices used were averages of the prices at harvesting and planting times. For manure, the price estimate of 0.15 Birr/kg for the Hararghe highlands by Storck et al. (1991) was used for this study.

6.5 The Empirical Results

The total factor productivity estimates along with the land productivity and factor intensity levels of the alternative cropping systems in Babile and Meta districts are presented in Tables 6.3 and 6.4, respectively. The productivity estimates, unlike their bilateral counterparts, allow us to compare a given cropping system with all other cropping systems. The results reveal considerable variation in total factor productivity, and thus resource use efficiency, among cropping systems in both agro-climatic zones. This means that much of the variation in resource use efficiency at farm level could be explained more by this variation in cropping systems.

In Babile, the cereal-pulse system performed better than the system with intercropped annuals, sole cropped annuals, and annual-perennial intercrops. The *haricot beans-improved maize* cropping system has turned out to be the most efficient system followed by the *haricot beans-local maize-local sorghum* cropping system. The later conforms with the practices of small farmers as the *haricot beans-local maize-local sorghum* is their dominant (43.8 percent) cropping system (Table 6.1) followed by the local maize-local sorghum (37.5 percent), which also gave high performance in terms of TFP (Table 6.3).

However, these results did not correspond to the actual practices of medium and large farmers, who chose sole cropping of cash crops (groundnuts and khat- Table 6.1) as well as sole food crops (local sorghum and improved maize) as their dominant cropping systems. As observed earlier, land availability for sole cropping is a key determinant of cropping system choices and possible reason behind such deviation. One should note, however, that sole cultivation of improved maize (ranking third in TFP) is a very dominant system (56.5 percent) among large farmers in Babile (Table 6.1). Regardless of its high productivity, the cereal-pulse system involving improved maize was not the dominant choice among farmers in Babile.

Sole cropping is generally a less efficient cropping strategy even in the case of improved crop varieties in Babile. For instance, the *haricot beans-improved maize* system is 40 percent more efficient than the sole *improved maize* system, indicating considerable efficiency gain from new technology through intercropping with pulses. However, improved sorghum is among the least efficient systems, even less than the local sorghum system, implying that new varieties of sorghum promoted in Babile are not that superior. While the results clearly show the dominance of maize (especially improved maize) over sorghum if productivity considerations are important, more farmers are growing sorghum (especially local) than maize. This may be due to the fact that local sorghum cultivars are more tolerant to drought that characterize this zone than improved maize (guaranteeing more stable harvest). Moreover, farmers tend to apply more purchased inputs such as fertilizer (see Table 6.3) to sole and intercropped sorghum plots than to maize plots in view of the relatively higher risk of maize crop failure (Bezabih, 2000). This confirms the importance of hedging against risk elements in farmers' choices of cropping systems when high production risks are involved such as in the dry land zone of Babile.

In Meta district, the results show that maize and potatoes (intercropped or sole) are the most efficient cropping practices (Table 6.4). These are also the dominant practices in this zone with improved maize more common among large farms versus local maize among smaller farms (Table 6.2). Table 6.2 shows that the maize-potatoes system, which is most efficient in Meta is more prevalent in small farms than in the medium and large farms implying that small farms use their highly scarce resources more efficiently than those facing less land constraints.

Table 6.3: Total factor productivity estimates for cropping systems in Babile

Cropping system	TFP	Land Productivity	Factor intensity	Labor	Oxen	Fertilizer	Seed
Groundnut	1.3710	1.1059	0.8066	0.7302	0.1846	0.0780	0.0072
Groundnut-Local sorghum	1.6848	1.3283	0.7884	1.1414	0.2886	0.1219	0.0113
Haricot beans-Improved maize	2.8560	2.1713	0.7603	0.5162	0.2098	0.0025	0.0781
Haricot beans-Improved maize-Local sorghum	1.5070	1.9359	1.2846	0.4414	0.2236	0.0578	0.0656
Haricot beans-local maize	0.9242	1.2655	1.3693	0.4455	0.2194	0.0866	0.0088
Haricot beans-Local maize-Local sorghum	2.7324	2.7770	1.0163	0.8767	0.3466	0.0475	0.0137
Haricot beans-Local sorghum	1.4060	1.9289	1.3719	0.7857	0.4677	0.1084	0.0075
Improved maize	1.9453	1.3917	0.7154	0.6382	0.2900	0.0764	0.0117
Improved maize-local sorghum	1.3698	1.5758	1.1504	0.8500	0.3794	0.1294	0.0130
Improved sorghum	1.0741	1.2904	1.2013	0.4247	0.2143	0.0690	0.0073
Khat-Groundnut	1.0000	1.0000	1.0000	0.7754	0.3537	0.0076	0.0137
Khat-local maize	0.7513	1.1743	1.5631	0.8003	0.3257	0.0683	0.0070
Local maize	1.1916	1.0782	0.9048	0.5617	0.2441	0.0897	0.0093
Local maize-Local sorghum	1.7656	1.8255	1.0339	0.6840	0.2805	0.0546	0.0149
Local sorghum	1.1557	1.3966	1.2085	0.7467	0.3388	0.1110	0.0120

Source: Own computation.

Moreover, apart from existing land constraints, input supply shortages and unavailability of credit make adoption of improved varieties more difficult for small farms and consequently they fail to take advantage of the higher efficiency and productivity of such technology. Therefore, inefficiencies among small farms may be considered exogenous, in general (i.e., part of the inefficiencies of the extension and credit systems that fail to adequately cater for their needs).

Although sole *improved maize* has turned out to be the second efficient, sole cropping is generally limited in Meta due to the critical land shortages in the wet highland zone compared to the dry land zone (Babile). The *improved maize-potatoes* system is 26 percent more efficient than the sole *improved maize* system, indicating considerable efficiency gain from new technology through intercropping with potatoes. On the other hand, intercropping of cereals with perennial cash crops such as khat is an inefficient practice. Furthermore, sorghum and the small cereals like wheat, barley, and tef have turned out to be among the least efficient cropping practices in Meta. This is probably due to the fact that less fertile degraded land is allocated to these crops in the wet highland zone that are highly eroded. It was observed during the survey that relatively more fertile plots were planted to maize while sloppy and degraded plots were planted with small cereals. Moreover, there are generally no improved technologies promoted in the wet highland zone to improve the productivity of these crops.

6.6 Conclusions

This chapter investigated the resource use efficiency of alternative cropping systems and technologies in two distinct agro-climatic zones in eastern Ethiopia. The total factor productivity, land productivity, and factor intensity levels of 15 cropping systems in the dry land zone and 14 cropping systems in the wet highland zone were derived. The results indicated considerable variation in resource use efficiency among the cropping systems in both areas, confirming that part of the variation in resource use efficiency at farm level could be explained by the variation in cropping systems.

The results for both study areas implied that as land and other resources become increasingly limiting and agricultural production highly conditioned by weather, farmers have greater incentives for pursuing more efficient cropping practices. When land available to a household is too small to produce subsistence requirements from sole cropping and risk considerations become increasingly important, farmers tend to intercrop in order to produce sufficient food for the household and hedge against production risks. But if sufficient land is available to support subsistence requirements, the farmer resorts more to sole cropping of both food staples and cash crops even though those may not be the most efficient. A good example is the production of groundnuts as a cash crop in Babile, which is especially common among large farmers in spite of its low efficiency, implying that efficiency considerations may be undermined by objectives of cash generation.

Table 6.4: Total factor productivity estimates for cropping systems in Meta

Cropping system	TFP	Land Productivity	Factor intensity	Labor	Oxen	Fertilizer	Seed
Barley	1.0000	1.000	1.000	0.1969	0.7032	0.0717	0.0281
Beans	0.7100	0.690	0.970	0.2211	0.6810	0.0443	0.0236
Haricot beans-Local maize-Local sorghum	1.3100	1.440	1.100	0.5620	0.4749	0.0182	0.0449
Improved maize	1.6800	3.750	2.230	0.5114	1.4032	0.2815	0.0339
Improved maize-Potatoes	2.1200	5.130	2.420	0.7076	1.2752	0.3287	0.1084
Khat-local maize	1.0800	2.100	1.940	1.3402	0.5609	0.0065	0.0323
Khat-Local maize-Potatoes	1.2000	3.010	2.510	0.8327	1.6159	0.0299	0.0315
Local maize	1.1300	1.930	1.720	0.5198	1.1303	0.0558	0.0140
Local maize-Local sorghum	1.3500	2.280	1.690	0.8698	0.7159	0.0818	0.0225
Local Maize-Potatoes	1.6100	2.420	1.500	0.4780	0.9229	0.0827	0.0165
Local sorghum	0.7400	1.100	1.480	0.7949	0.5855	0.0860	0.0136
Potatoes	1.9200	2.800	1.460	0.2631	1.0454	0.0731	0.0784
Tef (Eragrostis Tef)	0.4200	0.600	1.420	0.4568	0.8620	0.0851	0.0160
Wheat	1.1100	1.460	1.320	0.3343	0.7411	0.2152	0.0294

Source: Own computation.