Why some community forests are performing better than others: a case of forest user groups in Nepal

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Summary

Management of many Nepalese forests has been devolved to local communities. Forest products, which are used by the community and which may also be traded, are essential contributors to community well-being. Forests are also important contributors of ecosystem services, such as flood protection and wildlife habitat. Nepalese communities were surveyed to measure flows of forest products from their community forests. A stochastic frontier analysis shows that communities are not producing forest products efficiently and there is potential for improvement. The results shows that forest products benefit and environmental performance are associated products. In addition, analysis reveals that factors such as social capital, support from government and knowledge in management contributes positively to the production efficiency. It is anticipated that these findings will contribute to community forest policy redesign and consequently to the welfare of communities.

Keywords: Community forestry, stochastic frontier, production efficiency, Nepal

1. Introduction

Management of many Nepalese forests has been handed over to local communities who have been entrusted to supply forest products and to address local environmental problems. Communities produce a range of forest products such as timber, fuel-wood, fodder and grasses from their Community Forests (CF) as well as ecosystem services, such as soil protection and wildlife conservation (Thoms, 2008).

There is limited information on the environmental or community welfare effects of entrusting communities to manage forests. There is some evidence at the household level (Adhikari, 2005; Malla, 2000; Thoms, 2008) that CFs increase income disparities within communities. Chakraborty (2001) and Iversen et al. (2006) have analysed institutional and economic stability effects of CFs at the community level. Several studies have indicated improvement in forest condition with community forestry. For example, Gautam et al. (2004b), found significant improvement in CF forest cover over the 25 years from 1976. Likewise, Gilmour et al. (2004) identified improvements in soil erosion control and water conservation in areas where communities have been able to regenerate forest cover in previously degraded land. However, these studies have taken into account only the biophysical aspects of the forest; they have ignored forest products. Studies undertaken so far have dealt only with consumption of forest products at the household level and have provided limited information on changes in environmental conditions. The relationship between community welfare from consumption of forest products and the condition of the natural environment in CFs has not been addressed.

2. Study Objectives

This research analyses the production performance of CF in terms of forest products benefits at the community level and investigates the relationship between forest production and various social, economic and environmental factors. The objectives of this study are;

- To identify production efficiency of CF by examining the relationship between ecosystem and community outcomes for CFs and,
- To investigate factors that influence production efficiency.

3. Community Forest Management in Nepal

Nepal forest resources have always had an important place in sustaining rural livelihoods. More than 80% of the population relies on forest products, such as fuel wood for cooking and heating and fodder and litter for livestock production (Thoms, 2008). Recognising the increasing depletion of forest resources and the Department of Forests' limited capacity to handle the problem alone, in 1978 the government introduced CF policy to seek local communities' cooperation in sustainable management and use of forest resources (Gautam et al., 2004a). The Forest Act 1993 and the Forest Regulation 1995 have guaranteed local communities rights to use forest resources. The CF management approach is one of the most cited success stories for managing common property resources (Adhikari, 2005; Chakraborty, 2001; Chaudhary, 2000). The Nepalese government intends to hand over all accessible forest to local communities for sustainable management and utilisation (Thoms, 2008).

Under CF management, parts of national forests are given to the local community, which is vested rights of access, use, exclusion and management of forest resources (Thoms, 2008). Each forest user group (FUG) prepares its own constitution for day-to-day group functioning, and a forest operational plan. The forest operational plan and the constitution are legal documents mutually agreed between the local community and the government. FUGs undertake development and forest management activities based on the provisions in these two documents. Up until 2009 more than 14,000 forest patches, about 22 % of Nepal's total forest area, had been entrusted to communities. Approximately 1.67 million households, about 35 % of the total population, have been involved in CF (Sharma, 2009).

4. Factors Influencing CF Production

Generally, in neo-classical production analysis the role of the agency which is responsible for production has been ignored. As a result, only transformation factors have been analysed, ignoring transaction factors. However, institutional economists such as North (1990) have demonstrated the role of the agency in the production process. North claimed that transformation factors, such as land, labour and capital, and transaction factors, which are related to social, economic and cultural aspects of the agency, are equally important. Similarly, Misra & Kant (2004) have demonstrated the significant role of social and economic factors related to agency in the production process of joint forest management in India.

Some studies have also documented the influence of group size, access to market and forest dependency on collective action in community-based management (Agrawal, 2001b; Agrawal & Chhatre, 2006; Gebremedhin et al., 2003). Agrawal (2000), in a study of community forestry in northern India, reported that forest condition was better in communities with larger numbers of households than in communities with small numbers of households. Similarly, Heltberg (2001) observed better collective action in large groups than in small groups. However, these outcomes are not consistent with collective action theory, which claims that the likelihood of collective action is higher in small user groups (Poteete & Ostrom, 2004).

Wade (1987) claimed that scarcity of resources encourages people to form groups to achieve intense needs, which would not be achievable by individual action. In contrast to earlier findings and claims, Bardhan (1993) has argued that medium levels of scarcity favour collective action. He argues that, at high levels of scarcity, people struggle for survival and the breaking of resource use rules is likely. At low levels of scarcity people get adequate access to resources, so they are reluctant to participate in collective resource management activities.

Many studies have demonstrated the influence of market access on CF management, but its role is widely contested. Some researchers (such as Agrawal, 2001a; Gebremedhin et al., 2003) have argued that better market access increases the value of resources, and thus produces an incentive for CF groups to heavily exploit the forest. Other researchers (such as Baland & Platteau, 1996; Pender & Scherr, 1999) have claimed that access to markets may lessen the contribution of group members to resource management since community members are less reliant on forest. Thus, the effect of market access on common resource management is ambiguous and site specific.

5. Framework for Analysis

Welfare of each individual community depends on the amount of utility that community derives from forest products and ecosystem services. The community produces various kinds of forest products by using input factors. According to Bergson (1938), a welfare model for the individual community may be written as;

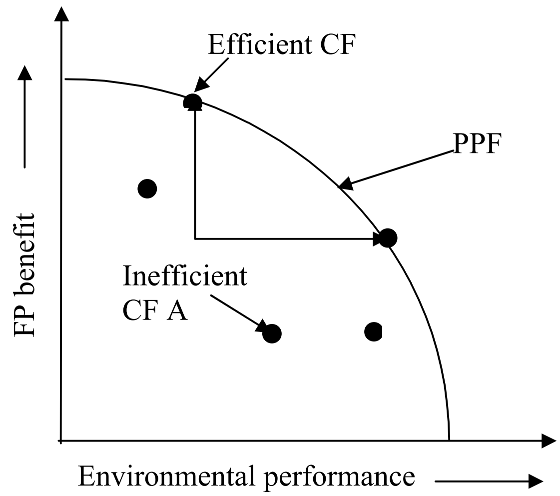
$$W_i = F(\mathbf{Y},\mathbf{X}) \quad (1)$$
$$\mathbf{Y} = g(\mathbf{X}, \theta) \quad (2)$$

Y is a vector of forest products an individual community consumes and **X** is an input vector, θ is other factors. Forest products include both direct consumable products such as timber, fodder and fuel wood and indirect products, such as soil and water conservation services. The production function is (2). Individual FUGs choose the vector of inputs for their CF, which determines **Y** through the production function, and hence community welfare. Some combinations of inputs will be less efficient than others, resulting in outputs **Y** that are not on the production possibilities frontier. This study seeks to identify that production possibility frontier and factors that may affect FUGs' abilities to reach the frontier.

6. Analytical Models

It was assumed that forest product benefits and environmental performance have a trade off relationship. Therefore, the production possibility frontier (PPF) model shown in figure 1 was assumed to exist. This model helps to explain the relationship between two outputs, by representing the different combination of outputs that can be produced with a given level of inputs (McCoy, 2003). Production (in)efficiency is measured by the deviation from the PPF.

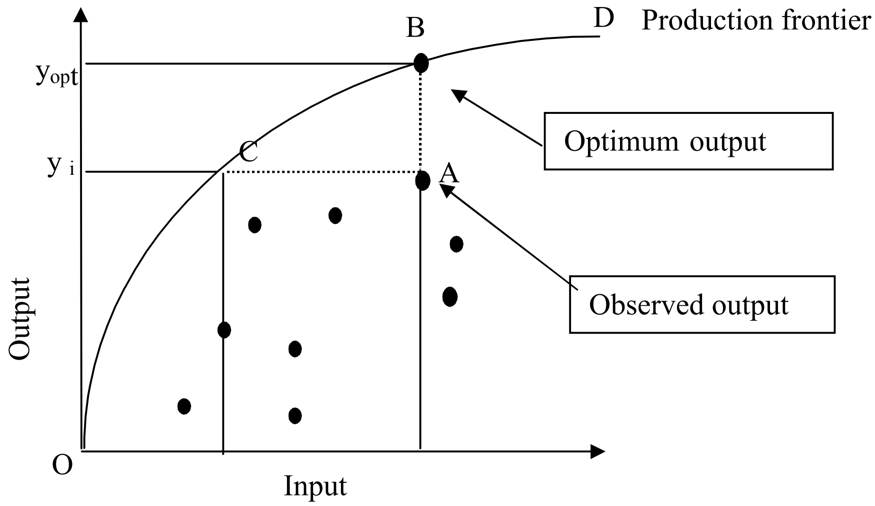
Figure 1. Production possibility frontier for two outputs



Data envelopment methods (DEA) and stochastic output distance models are used to estimate the PPF in multiple outputs cases. DEA does not require any assumption about specific functional form (Cooper et al., 2006; Forsund et al., 1980) and can handle multiple inputs and outputs together (Ondrich & Ruggiero, 2001). However, DEA methods are criticised for various reasons. First, DEA measures efficiency relative to other producers. Hence, by adding an extra producer into the analysis the efficiency scores may change, especially if the added producer lies along the frontier. Second, efficiency scores calculated using DEA are sensitive to outliers (Nyshadham & Rao, 2000; Simar, 2007). Third, DEA methods assume that the entire deviation of a producer from the production frontier is because of inefficiency (Coelli, 1995; Latruffe et al., 2005). This assumption has enormous implications in efficiency calculation.

Estimation of PPF by using stochastic output distance functions depends on the relationship between outputs. For example, the Cobb-Dougals functional form is not appropriate, since it has different curvature (Kumbhakar &Knox Lovell, 2000). An alternative to stochastic output distance functions, in a single output PPF model shown in the Figure 2, which is used in this study to analyse production efficiency.

Figure 2. The production possibility frontier model for one output



Curve OD represents the PPF, which envelops all the possible productions for varying levels of the inputs. Production efficiency is measured relative to OD. Efficient units are those operating on the production frontier (e.g. B), while inefficient ones are below the production frontier.

Two groups of methods have been used for estimating the production possibility frontier, thereby measuring efficiency; deterministic methods, such as (DEA), and the stochastic frontier method. Because of the various criticism of the DEA method, the stochastic frontier model (SFM) is preferred. The SFM assumes that outputs (and their deviations from the PPF) are a function of inputs, inefficiency and random error. In the SFM inefficiency is identified with a disturbance term in the production function (Greene, 1993). A general stochastic production function with single output is given by;

$$Y_i = f(x_i; \beta).\exp(\varepsilon_i), \qquad (3)$$

$$\varepsilon_i = v_i - u_i.$$

Where Y_i denotes output, x_i denotes a set of inputs, β is set of parameters to be estimated and i denotes individual producers. ε_i is a composed error term assumed to consist of two elements, v_i and u_i . v_i is random error and u_i is a non negative variable that accounts for technical inefficiency.

6.1 Functional Form for Stochastic Frontier Analysis

Several studies have used the translog (TL) functional form to estimate the PPF (Bigsby, 1994; Lien et al., 2007; Parikh et al., 1995). The TL functional form is flexible, without prior restrictions on elasticities of substitution or returns to scale (Bigsby, 1994; Coelli, 1995). However, there is a risk of multicollinearity when the number of parameters to be estimated is large and numbers of observations are few (Siry & Newman, 2001). The Cobb Douglas (CD) functional form is more appropriate in that situation. Since this study involves eight inputs and sample size is relatively small, the CD functional form was used to estimate the PPF.

There were two outputs of concern – forest products and environmental quality. The SFM does not allow both to be dependent variables, so forest products were used and environmental condition was treated as an independent variable[1]. A CD production function of the following form was used;

$$\ln Y_j = \beta_0 + \sum \beta_i \ln X_{ij} + \varepsilon_j \quad (4)$$

Y_j denotes the direct benefits per hectare from CF, β_0 is an intercept, β_j are parameters to be estimated, X_{ij} is input i, with one of the X_is being environmental quality, and ε_j is a composed error term defined as;

$$\varepsilon_i = v_i - u_i \quad (5)$$

v_i represents random error and u_i accounts for technical inefficiency. v_i is assumed to have a symmetric normal distribution [$v_i \sim N(0, \sigma_u^2)$], whereas u_i is assumed to have a non-negative half normal distribution with $|N(0, \sigma_u^2)|$.

Since v_i and u_i follow two different distributions, (v_i-u_i) is asymmetrically distributed and negatively skewed. Following Jondrow et al.(1982), maximum likelihood estimation of equation (4) yields consistent estimators for β, λ and σ^2, $\lambda=\sigma_u/\sigma_v$ and $\sigma^2=\sigma^2_u + \sigma^2_v$.

Efficiency of CF_i is the conditional mean of u_i for given ε_i, as defined by equation (6):

$$\hat{u}_i = E(u_i \mid \varepsilon_i) = \sigma_* \left[\frac{f(\varepsilon\lambda/\sigma)}{1 - F(\varepsilon\lambda/\sigma)} - \left(\frac{\varepsilon\lambda}{\sigma}\right) \right], \quad (6)$$

where f (.) and F (.) represent the standard normal density function and cumulative normal density function respectively, and $\sigma_* = \sigma_u\sigma_v/\sigma$. Once estimates of u_i are obtained from equation (6), estimates of efficiency of each CF can be calculated using equation (7);

$$TE_i = \exp(-\hat{u}_i), \quad (7)$$

6.2 Model to Explain Production Efficiency

This study not only aimed at ranking CFs according to efficiency, but also to explain factors influencing the ranking using an econometric model. An ordered logit model was used for this purpose because CFs were grouped into three classes based on estimated efficiencies (Lu, 1999).

6.3 Analytic Network Process

The Analytic Network Process (ANP) was used to calculate the environmental performance of individual CFs. The ANP is a mathematical method based on the theory of ratio scale measurement (Herath, 2004), in which a mathematical technique is used to obtain quantitative values from qualitative comparisons (Alphonce, 1997; Duke & Aull-Hyde, 2002). The ANP method decomposes the decision problem into clusters and elements (Alphonce, 1997; Herath, 2004) which are judged qualitatively.

[1] Attempts to apply output distance function models to these data failed. The reason for that failure will be discussed in Section 8.

The ANP models dependencies both within and between the clusters (inner dependence and outer dependence) (Saaty, 1999), allowing calculation of preference scores when various clusters are related to each other. Participants answer pairwise comparison questions to make the required qualitative judgements. The first set of questions concerned pairwise comparisons between elements or clusters, and the second set of questions elicited relative importance of elements or clusters in a ratio scale. The ratio scales are converted into preference or priority weights by using the super matrix technique (Neaupane & Piantanakulchai, 2006).

7. Data Collection

7.1 Method

A survey of 60 community forests from two districts was carried out during March and April 2009. Non random purposive sampling was used. CFs were selected to represent various forest attributes and community characteristics, such as forest type, heterogeneity among FUG members, access to market, area of forests and number of households involved. Two questionnaires were used, one for socioeconomic information related to the community and the other for ANP. A pre-test of the questionnaires checked clarity and item reliability.

7.2 Study Area

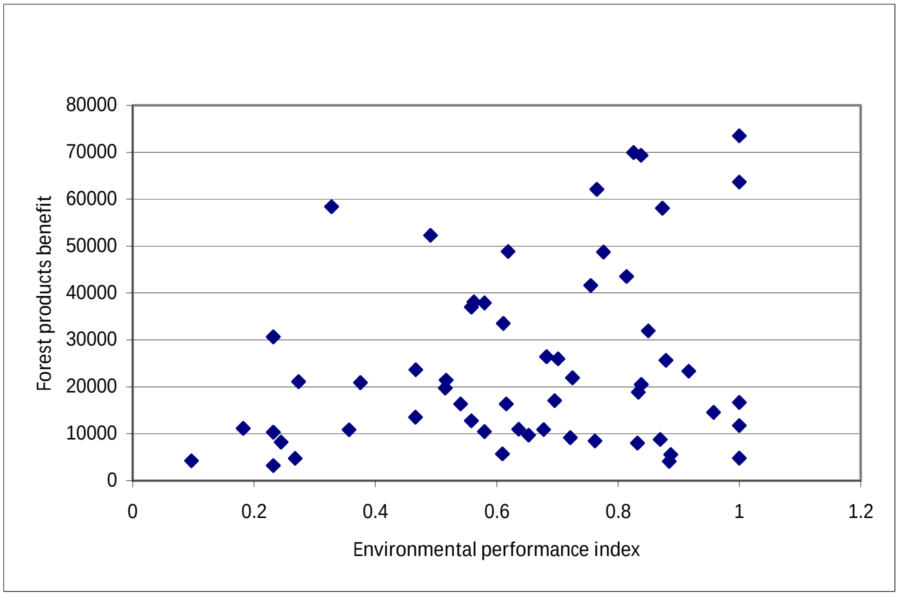
The study was undertaken in *Makawanpur* and *Kavre Palanchok* districts of the Middle Hills (MH) of Nepal. The MH region forms the major central belt of Nepal and occupies about 30 % of the country. The two districts have similar social, cultural and economic characteristics and follow similar forest management practices. These districts were selected for two main reasons. First, they have a history of CF management of more than two decades (Adhikari, 2006; District Forest Office, 2008), being pioneer districts for CF (Acharya et al., 2004). Second, the principal researcher was involved in various community forestry management activities in these two districts, facilitating the field work.

8. Findings and Discussion

8.1 Production Frontier

A scatter plot of forest product benefits and environmental performance is shown in Figure 3. It was expected the frontier between forest products benefits and environmental performance would have a negative slope; however, there is not the case for these data. This explains why stochastic output distance functions and DEA models were not appropriate and leads to the use of a single output SFM to estimate production function.

Figure 3. Forest products benefit and environmental performance



In order to estimate the PPF, benefits from forest products per hectare of forest were used as the dependent variable and various socioeconomic factors and environmental condition were used as independent variables (inputs). The Cobb –Douglas functional form was used to specify the stochastic PPF (Table 1).

Table 1. Stochastic PPF: Dependent variable = Benefit per hectare from forest products (in Nepalese Rupees)

Variables	Coefficient	Standard error	*t*-ratio
Constant	8.7706***	0.9110	9.6272
Ln Distance to government office	-0.0733*	0.0429	-1.7070
Ln CF area (ha)	-0.5253***	0.1172	-4.4840
Forest products sold in market or not	0.4120**	0.1776	2.3196
Ln Heterogeneity of CFUG	-1.1041***	0.2674	-4.1293
Ln Forest product dependency	0.4084**	0.1598	2.5552
Ln Number of households	0.6713***	0.1535	4.3743
Ln Environmental performance index	0.4361***	0.1650	2.6428
Variance parameters for compound error			
$\lambda = \sigma_u / \sigma_v$	1.4651***	0.5167	2.8354
$\sigma = \sqrt{\sigma_u^2 + \sigma_v^2}$	0.7497***	0.0110	68.1973

Note: ***, ** and * denote statistical significance at the 0.01, 0.05 and 0.10 levels respectively.

The stochastic PPF demonstrates that socio economic factors other than traditional input factors such as land, labour and capital have contributed significantly to forest production.

The coefficient for distance to the government forest office is negative, but significant at the10% level. This result indicates that CF productivity increases the closer the CF is to a government office. It is very likely that CFs, which were near to the government office, might have better informed regarding forest management practices, forest -related rules and regulation.

CF area has a significant negative impact on forest production. The relationship between forest area and per hectare productivity has been widely debated. For example, Siry & Newman (2001) have found per hectare a positive relationship between timber production and forest area in Polish state forests. On the other hand, Misra & Kant (2004) have reported a negative association between forest area and productivity in India.

Better CF links to the market positively contribute to forest production. It seems that the CFs which have established links to sell forest products in the market were likely to produce more forest products than those which did not have a link to a market. This finding is expected and is consistent with the findings of other studies, such as Agrawal & Yadama (1997)) who found that links to markets enhance the harvesting of forest products in India.

The inverse relationship of forest production with homogeneity implies that a homogenous FUG produces more forest products than a heterogeneous FUG. A possible reason may be that heterogeneity delays the decision making process because of higher transaction costs in heterogeneous groups (Adhikari & Lovett, 2006; Misra & Kant, 2005). Misra & Kant (2004) found a negative, but elastic, relationship between forest product supply and forest user group heterogeneity in India and similar results have occurred in other empirical studies (Adhikari & Lovett, 2006; Gautam, 2007; Varughese & Ostrom, 2001).

Forest product dependency of FUGs is positively related with CF production. High dependency on the CF may indicate that either community FUGs have fewer substitutes available, or they have less capacity for using substitutes for forest products (Agrawal & Chhatre, 2006; Kant, 2000). Similarly, at the household level in Southern Malawi higher dependency on forest products induced more forest products collection (Fisher, 2004). In contrast, Misra & Kant (2004) have noted that dependency of the FUG has no significant contribution to the supply of forest products in India. Contradictory results may arise because of differences in the roles of CFs in Nepal and joint forest management in India, there is more government control in decision making in India (Kumar, 2002). Government control over harvesting may prevent forest users from collecting forest products according to their preferences.

The positive coefficient on number of households in the community indicates that bigger communities generate more forest products than smaller communities do. Misra & Kant (2004) claimed that in community based forest management, each household can be considered as a labour input, so they contribute to the production process. However, they have pointed out that the role of group size in forest production depends on the nature of the group. Groups highly concerned about the environment may reduce the production of forest products. On the other hand, a medium level or low level of concern with the environment may contribute to higher forest production.

The positive sign on the environmental performance index indicates that forests in better environmental condition produce more. This result is similar to what Misra & Kant (2004) found in joint forest management in India, where forest production increases with increase in canopy cover. However, Lichtenstein & Montgomery (2003) demonstrated that biodiversity conservation, measured by vertebrate species diversity, and timber production are inversely related. They found that within a certain range of biodiversity, vertebrate biodiversity could be increased with little loss of timber production. However, as biodiversity approached its maximum the opportunity cost of conservation increased at an increasing rate.

8.2 Production Efficiency

Table 1 estimates for λ (1.4651) and σ (0.7497) are large and significantly different from one and zero respectively, indicating that variance associated with inefficiency (u_i) dominates variance associated with random error (v_i). The significant value of λ identifies inefficiency in the production process (Cooper & Cohn, 1997).

Production efficiency estimates for individual CFs appear in Appendix1. Production efficiency ranges from 0.2942 to 0.8298, with an average efficiency of 0.6281. This implies that if the average CF in the sample was to achieve full production efficiency, then the average CF could achieve approximately 32% more forest products from the same inputs, including environmental condition. The least efficient CF could improve production by 64%.

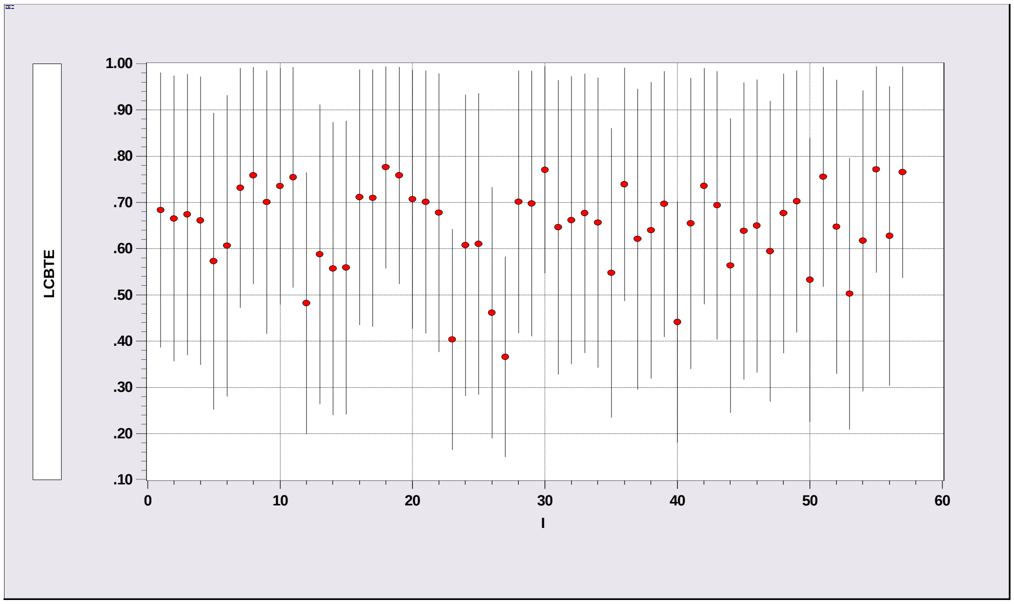
The distribution of CF production efficiency measures is presented in Table 2. The most common decile for production efficiency was 0.70 to 0.80 (26.3% of CFs), followed by 0.60 to 0.70 (21.1%). Only 14% of CFs have production efficiency greater than 0.80, suggesting that only a small proportion of CFs were operating close to the efficiency frontier.

Table 2. Frequencies of CF production efficiencies

Efficiency	Number of CF	Percent
>0.80	8	14.04
0.80-0.70	15	26.32
0.70-0.60	12	21.05
0.60-0.50	10	17.54
0.50-0.40	7	12.28
0.40-0.30	5	8.77
Sample size	57	
Mean efficiency	62.81	
Minimum	29.42	
Maximum	82.98	

Various sources of uncertainty, such as sampling error and different sets of assumptions made in order to estimate the frontier, make the point estimate uncertain (Brummer, 2001). Following Bera & Sharma (1999) and Kim & Schmidt (2000), confidence intervals for production efficiency scores were estimated (Appendix 1). Confidence intervals are wide and overlapping (Figure 4). Confidence interval bounds for the CF with the highest point estimate of efficiency are 0.5567 and 0.9941, with width of 0.4374. Likewise, bounds for the CF with the lowest point estimate of efficiency are 0.1485 and 0.5826, with width of confidence interval of 0.4341. CFs which are at the top and bottom ranks, have overlapping confidence intervals, so an alternative test of efficiency differences is required.

Figure 4. 95% confidence intervals for production efficiency



A Monte Carlo simulation was carried out to test differences in efficiency between each pair of CFs. Efficiency of nineteen CFs was not significantly different from any others. However, there was one group of CFs that was more efficient than some other CFs and another group that was less efficient than some other CFs. This was the basis for classifying efficiency scores into three groups (Appendix 2). CFs 1 to 8 form the most efficient group, and CFs 51 to 57 are likely to be the least efficient CFs. The remainder, CFs 9 to 50, are indeterminate, forming an intermediate group.

8.3 Factors Explaining Production Efficiency

Membership of the three groups of CFs identified by the Monte Carlo simulation was used as the dependent variable in an ordered logit model which used CF-related variables as regressors (Table 3).

Factors such as time since CF establishment, growing stock of the forest and support from government staff, positively contribute to production efficiency. CFs which have been established for a long time were more efficient. This may be due to managerial skills, which FUG members have learnt over time (Lindara et al., 2006).

Table 3. Factors explaining production efficiencies

Variable	Coefficient	Standard Error	t-ratio
Constant	-5.3842**	2.7194	-1.98
Time since CF establishment(years)	0.1193**	0.0549	2.1708
Social capital index	1.1317*	0.6433	1.7593
Growing stock of CF (m^3/ha)	0.0069**	0.0031	2.2411
Support from government staff (yes=1 ,else 0)	1.57***	0.5069	3.097
Caste heterogeneity in EC	-2.0297**	0.9278	-2.1875
Mu(1)	3.1949***	0.4997	6.3941

Note: ***, ** and * denote statistical significance at the 0.01, 0.05 and 0.10 levels respectively.

CFs which had high social capital were more efficient than CFs with low social capital, consistent with the finding by Van Ha et al.(2006) that high levels of social capital improved production efficiency of paper recycling households in Vietnam. It is possible that social capital reduces transaction costs among FUG members and hence helps to enhance efficiency. Likewise, additional support from government staff made CFs more efficient. This result is consistent with that obtained by Lindara et al.(2006), who found increases in the number of farm visits by extension officers decreased inefficiency of Sri Lankan farmers.

CFs with higher growing stock appear to be more efficient than CFs with lower growing stock. High growing stock indicates more forest product availability per unit area of forest.

The coefficient for caste heterogeneity in the FUG executive committee is negative and significant. This implies that same-caste executive committees were more efficiently than mixed-caste executive committees. One possible reason for the negative sign is that heterogeneity affects interactions among executive committee members, incurring high transaction costs.

9. Conclusions and Recommendations

The aim of this study was to estimate production efficiency and to indentify the factors that influence production efficiency of community forestry in Nepal. The result of the analysis demonstrates that factors such as heterogeneity of the FUG, dependency of the FUG, environmental performance and other factors affect CF production. The stochastic frontier analysis shows that environmental performance and CF production are not competing objectives. This association implies there is a possibility for augmenting forest product supply along with environmental performance of CF.

Average CF production efficiency is 62.81%, which indicates that there is great potential for improvement in production efficiency. The stochastic frontier analysis supports the importance of the role of transaction factors, such as heterogeneity and dependency, in the production process. This study identifies factors such as time since establishment of CF, social capital, growing stock and support from government staff contributed positively to production efficiency. Some of these items provide opportunities for enhancing CF efficiency through government policy initiatives. On the other hand, heterogeneity in executive committee members decreased production efficiency. However, making an executive committee more homogenous is against CF policy, which seeks representation from all social and economic groups, so is not an avenue for attaining improvements in efficiency.

Since this study was carried out in the middle hills of Nepal, results cannot be generalised to other parts of Nepal. However, use of the same approach in other parts of Nepal would be useful for better understanding CF production possibilities.

References

Acharya, U., Petheram, R. J., & Reid, R. (2004). Concepts and perceptions of biodiversity in community forestry, Nepal. *Small-Scale Forestry, 3*(3), 401-410.

Adhikari, B. (2005). Poverty, property rights and collective action: understanding the distributive aspects of common property resource management. *Environment and Development Economics, 10*(01), 7-31.

Adhikari, B. (2006). Transaction costs and community-based natural resource management in Nepal. *Journal of Environmental Management, 78*(1), 5-15.

Adhikari, B., & Lovett, J. C. (2006). Institutions and collective action: Does heterogeneity matter in community-based resource management? *Journal of Development Studies, 42*(3), 426-445.

Agrawal, A. (2000). Small is beautiful, but is larger better? forest management institutions in the Kumaon Himalaya, India In C. C. Gibson, M. A. McKean & E. Ostrom (Eds.), *People and forests: Communities, institutions, and governance* (pp. 57-85). London: The MIT press.

Agrawal, A. (2001a). Common property, forest management and the Indian Himalaya. *Contributions to Indian Sociology, 35*(2), 181-212.

Agrawal, A. (2001b). Common property institutions and sustainable governance of resources. *World Development, 29*(10), 1649-1672.

Agrawal, A., & Yadama, G. (1997). How do Local Institutions Mediate Market and Population Pressures on Resources? Forest Panchayats in Kumaon, India. *Development and Change, 28*(3), 435-465.

Agrawal, A., & Chhatre, A. (2006). Explaining success on the commons: Community forest governance in the Indian Himalaya. *World Development, 34*(1), 149-166.

Alphonce, C. B. (1997). Application of the analytic hierarchy process in agriculture in developing countries. *Agricultural Systems, 53*(1), 97-112.

Baland, J. M., & Platteau, J. P. (1996). *Halting degradation of natural resources: is there a role for rural communities?* : Food & Agriculture Org.

Bardhan, P. (1993). Analytics of the institutions of informal cooperation in rural development. *World Development, 21*(4), 633-639.

Bera, A. K., & Sharma, S. C. (1999). Estimating production uncertainty in stochastic frontier production function models. *Journal of Productivity Analysis, 12*(3), 187-210.

Bergson, A. (1938). A Reformulation of Certain Aspects of Welfare Economics. *The Quarterly Journal of Economics, 52*(2), 310-334.

Bigsby, H. R. (1994). Production structure and the Australian sawmilling industry. *Australian Journal of Agricultural Economics, 38*(03)

Brummer, B. (2001). Estimating confidence intervals for technical efficiency: the case of private farms in Slovenia. *European Review of Agricultural Economics, 28*(3), 285.

Chakraborty, R. N. (2001). Stability and outcomes of common property institutions in forestry: evidence from the Terai region of Nepal. *Ecological Economics, 36*(2), 341-353.

Chaudhary, R. P. (2000). Forest conservation and environmental management in Nepal: a review. *Biodiversity and Conservation, 9*(9), 1235-1260.

Coelli, T. J. (1995). Recent developments in frontier modelling and efficiency measurement. *Australian Journal of Agricultural Economics, 39*, 219-246.

Cooper, S. T., & Cohn, E. (1997). Estimation of a frontier production function for the South Carolina educational process. *Economics of Education Review, 16*(3), 313-327.
Cooper, W. W., Seiford, L. M., & Tone, K. (2006). *Introduction to data envelopment analysis and its uses*. New York Springer science & Business media Inc.
District Forest Office. (2008). *Samudaik Ban Upbhokta hamuah Anugaman tatha Mulyankan Bisleshan Pratibedan (Community Forestry User Group's Monitoring and Evaluation Analysis Report* Hetauda,Nepal: Department of Forest.
Duke, J. M., & Aull-Hyde, R. (2002). Identifying public preferences for land preservation using the analytic hierarchy process. *Ecological Economics, 42*(1-2), 131-145.
Forsund, F. R., Lovell, C. A. K., & Schmidt, P. (1980). A survey of frontier production functions and of their relationship to efficiency measurement. *Journal of Econometrics, 13*(1), 5-25.
Gautam, A. P. (2007). Group size, heterogeneity and collective action outcomes: Evidence from community forestry in Nepal. *The International Journal of Sustainable Development and World Ecology, 14*(6), 574-583.
Gautam, A. P., Shivakoti, G. P., & Webb, E. L. (2004a). A review of forest policies, institutions, and changes in the resource condition in Nepal. *The International Forestry Review, 6*(2), 136-148.
Gautam, A. P., Shivakoti, G. P., & Webb, E. L. (2004b). Forest Cover Change, Physiography, Local Economy, and Institutions in a Mountain Watershed in Nepal. *Environmental Management, 33*(1), 48-61.
Gebremedhin, B., Pender, J., & Tesfay, G. (2003). Community natural resource management: the case of woodlots in Northern Ethiopia. *Environment and Development Economics, 8*(01), 129-148.
Gilmour, D., Malla, Y., & Nurse, M. (2004). *Linkages between community forestry and poverty*. Retrieved May 31, 2010, from http://www.recoftc.org/site/fileadmin/docs/publications/The_Grey_Zone/RECOFTCStrategicPlan04-09/Community_forestry_and_poverty.pdf
Greene, W. (Ed.). (1993). *The econometric approahc to efficiency analysis* New York Oxford University Press.
Herath, G. (2004). Incorporating community objectives in improved wetland management: the use of the analytic hierarchy process. *Journal of Environmental Management, 70*(3), 263-273.
Jondrow, J., Knox Lovell, C. A., Materov, I. S., & Schmidt, P. (1982). On the estimation of technical inefficiency in the stochastic frontier production function model. *Journal of Econometrics, 19*(2-3), 233-238.
Kant, S. (2000). A dynamic approach to forest regimes in developing economies. *Ecological Economics, 32*(2), 287-300.
Kim, Y., & Schmidt, P. (2000). A review and empirical comparison of Bayesian and classical approaches to inference on efficiency levels in stochastic frontier models with panel data. *Journal of Productivity Analysis, 14*(2), 91-118.
Kumar, S. (2002). Does "Participation" in Common Pool Resource Management Help the Poor? A Social Cost-Benefit Analysis of Joint Forest Management in Jharkhand, India. *World Development, 30*(5), 763-782.
Latruffe, L., Balcombe, K., Davidova, S., & Zawalinska, K. (2005). Technical and scale efficiency of crop and livestock farms in Poland: does specialization matter? *Agricultural Economics, 32*(3), 281-296.

Lichtenstein, M. E., & Montgomery, C. A. (2003). Biodiversity and Timber in the Coast Range of Oregon: Inside the Production Possibility Frontier. *Land Economics, 79*, 56-73.

Lien, G., Stordal, S., & Baardsen, S. (2007). Technical efficiency in timber production and effects of other income sources *Small-Scale Forestry,* (6), 65-78.

Lindara, L., Johnsen, F. H., & Gunatilake, H. M. (2006). Technical efficiency in the spice based agroforestry sector in Matale district, Sri Lanka. *Agroforestry Systems, 68*(3), 221-230.

Lu, M. (1999). Determinants of residential satisfaction: ordered logit vs. regression models. *Growth and Change, 30*(2), 264-287.

Malla, Y. B. (2000). Impact of community forestry policy on rural livelihoods and food security in Nepal. *Unsylva*, 37-45.

McCoy, N. H. (2003). Behavioral externalities in natural resource production possibility frontiers: integrating biology and economics to model human-wildlife interactions. *Journal of Environmental Management, 69*(1), 105-113.

Misra, D., & Kant, S. (2004). Production analysis of collaborative forest management using an example of joint forest management from Gujarat, India. *Forest Policy and Economics, 6*(3/4), 301-320.

Misra, D., & Kant, S. (2005). Economic efficiency and shadow prices of social and biological outputs of village-level organizations of joint forest management in Gujarat, India. *Journal of Forest Economics, 11*(3), 141.

Neaupane, K. M., & Piantanakulchai, M. (2006). Analytic network process model for landslide hazard zonation. *Engineering Geology, 85*(3-4), 281-294.

Nyshadham, E. A., & Rao, V. K. (2000). Assessing efficiency of European airports: a total factor productivity approach. *Public Works Management & Policy, 5*(2), 106.

Ondrich, J., & Ruggiero, J. (2001). Efficiency measurement in the stochastic frontier model. *European Journal of Operational Research, 129*(2), 434-442.

Parikh, A., Ali, F., & Shah, K. (1995). Measurement of Economic Efficiency in Pakistani Agriculture. *American Journal of Agricultural Economics, 77*, 675-675.

Pender, J. L., & Scherr, S. J. (1999). *Organizational development and natural resource management: Evidence from central Honduras*. Retrieved May 27, 2010, from http://www.ifpri.org/sites/default/files/publications/eptdp49.pdf

Poteete, A. R., & Ostrom, E. (2004). Heterogeneity, Group Size and Collective Action: The Role of Institutions in Forest Management. *Development and Change, 35*(3), 435-461.

Rahman, S. (2003). Profit efficiency among Bangladeshi rice farmers. *Food Policy, 28*(5-6), 487-503.

Saaty, T. L. (1999). *Fundmentals of the analytic network process* Paper presented at the International symposium on the analytic hierarchy process.

Sharma, A. R. (2009). *Impact of community forestry on income distribution.* Unpublished doctoral thesis, Tribhuvan University, Kathmandu, Nepal.

Simar, L. (2007). How to Improve the Performances of DEA/FDH Estimators in the Presence of Noise? *Journal of Productivity Analysis, 28*(3), 183-201.

Siry, J. P., & Newman, D. H. (2001). A stochastic production frontier analysis of Polish state forests. *Forest Science, 47*(4), 527.

Thoms, C. A. (2008). Community control of resources and the challenge of improving local livelihoods: A critical examination of community forestry in Nepal. *Geoforum, 39*(3), 1452-1465.

Van Ha, N., Kant, S., & Maclaren, V. (2006). Relative shadow prices of social capital for household-level paper recycling units in Vietnam. *Ecological Economics, 57*(3), 520-533.

Varughese, G., & Ostrom, E. (2001). The Contested Role of Heterogeneity in Collective Action: Some Evidence from Community Forestry in Nepal. *World Development, 29*(5), 747-765.

Wade, R. (1987). The management of common property resources: collective action as an alternative to privatisation or state regulation. *Cambridge Journal of Economics, 11*(2), 95.

Appendix 1 CF technical efficiency and 95 % conficence intervals

SN	Name of CF	Technical efficiency	Rank	Confidence bound (95%)		Interval difference (UCB-LCB)
				Lower	Upper	
1	Bageshari	0.7569	13	0.3856	0.9806	0.5950
2	Bajrabarhi	0.6491	28	0.3555	0.9739	0.6183
3	Balkumari	0.6662	27	0.3693	0.9773	0.6080
4	Baluwabharreng	0.6400	30	0.3485	0.9718	0.6233
5	Banaskhandi	0.4896	46	0.2510	0.8936	0.6426
6	Bansgopal	0.5388	43	0.2799	0.9316	0.6518
7	Basuki	0.7693	12	0.4719	0.9902	0.5182
8	Betkholsi	0.8079	5	0.5232	0.9929	0.4697
9	Bhagawan thumki	0.7174	20	0.4153	0.9850	0.5697
10	Bhairabkali	0.7749	11	0.4788	0.9906	0.5118
11	Bhotekhola	0.8021	8	0.5149	0.9925	0.4776
12	Bhutan devi	0.3923	53	0.1986	0.7646	0.5660
13	Bungdal	0.5103	45	0.2629	0.9116	0.6487
14	Chakradevi	0.4700	49	0.2401	0.8735	0.6334
15	Chhanauta	0.4723	48	0.2413	0.8760	0.6347
16	Chhilli bans	0.7362	14	0.4344	0.9871	0.5527
17	Chhitrepani	0.7330	15	0.4311	0.9868	0.5557
18	Chuchekhola	0.8298	1	0.5567	0.9941	0.4374
19	Chulipran	0.8076	6	0.5228	0.9928	0.4701
20	Chunnidevi	0.7285	16	0.4265	0.9863	0.5599
21	Churekalilek	0.7180	19	0.4159	0.9851	0.5692
22	Dangdunage	0.6741	24	0.3759	0.9787	0.6029
23	Dhaneshwar	0.3250	56	0.1641	0.6424	0.4783
24	Dipat	0.5409	42	0.2812	0.9330	0.6518
25	Dovan khola	0.5451	41	0.2837	0.9354	0.6517
26	Ektare	0.3739	54	0.1891	0.7329	0.5438
27	Gosaikunda	0.2942	57	0.1485	0.5826	0.4341
28	Hariyali	0.7190	18	0.4169	0.9852	0.5683
29	Jarungshakti	0.7121	21	0.4102	0.9844	0.5742
30	Jyoti	0.8233	3	0.5464	0.9938	0.4474
31	Kalabanzar	0.6116	35	0.3276	0.9641	0.6365
32	Kalika	0.6418	29	0.3498	0.9722	0.6224
33	Kalika chandika	0.6718	25	0.3739	0.9783	0.6044
34	Kalika hariyali	0.6319	31	0.3424	0.9698	0.6274
35	Kalilek	0.4587	50	0.2339	0.8606	0.6267
36	Kotthumki	0.7810	9	0.4865	0.9911	0.5046
37	Laljhadi	0.5634	39	0.2952	0.9452	0.6500
38	Lother	0.5990	36	0.3188	0.9599	0.6412
39	Mahila srijana	0.7102	22	0.4083	0.9841	0.5758
40	Manakamana (Manahari)	0.3564	55	0.1801	0.7014	0.5213
41	Mangleshar	0.6281	32	0.3395	0.9688	0.6293
42	Mankamana(Gadi)	0.7755	10	0.4795	0.9906	0.5111
43	Namuna	0.7050	23	0.4034	0.9835	0.5800
44	Navalpur sarswati	0.4775	47	0.2443	0.8816	0.6373
45	Newreni chisapani	0.5961	37	0.3167	0.9589	0.6422
46	Parbati mahila	0.6182	33	0.3323	0.9660	0.6338
47	Patleshar	0.5203	44	0.2688	0.9192	0.6505
48	Rani	0.6715	26	0.3737	0.9783	0.6046
49	Resheswar	0.7205	17	0.4184	0.9854	0.5670
50	Saradidevei	0.4421	51	0.2249	0.8396	0.6148
51	Shikaribas	0.8036	7	0.5170	0.9926	0.4756
52	Siddhakali	0.6135	34	0.3289	0.9647	0.6357
53	Simpani devkot	0.4115	52	0.2086	0.7956	0.5870
54	Soltu	0.5566	40	0.2909	0.9418	0.6509
55	Subhlaxmi	0.8241	2	0.5476	0.9938	0.4462
56	Sundar	0.5759	38	0.3033	0.9509	0.6477
57	Thakaldanda	0.8165	4	0.5359	0.9934	0.4575

Notes: LCB= Lower confidence bound, UCB= Upper confidence bound

Appendix 2 Ranking of CFs using Monte Carlo simulation

Name of CF	PE	Rank	Number of CF different from	Significantly different from
Chuchekhola	0.8298	1	7	CF57-CF50
Subhlaxmi	0.8241	2	7	CF57-CF50
Jyoti	0.8233	3	6	CF57-CF52
Thakaldanda	0.8165	4	6	CF57-CF52
Betkholsi	0.8079	5	6	CF57-CF52
Chulipran	0.8076	6	6	CF57-CF52
Shikaribas	0.8036	7	6	CF57-CF52
Bhotekhola	0.8021	8	6	CF57-CF52
Kotthumki	0.7810	9	5	CF57-CF53
Mankamana(Gadi)	0.7755	10	5	CF57-CF53
Bhairabkali	0.7749	11	5	CF57-CF53
Basuki	0.7693	12	4	CF57-CF54
Bageshari	0.7569	13	2	CF57-CF56
Chhilli bans	0.7362	14	3	CF57-CF55
Chhitrepani	0.7330	15	3	CF57-CF55
Chunnidevi	0.7285	16	3	CF57-CF55
Resheswar	0.7205	17	2	CF57-CF56
Hariyali	0.7190	18	3	CF57-CF55
Churekalilek	0.7180	19	3	CF57-CF55
Bhagawan thumki	0.7174	20	2	CF57-CF56
Jarungshakti	0.7121	21	2	CF57-CF56
Mahila srijana	0.7102	22	2	CF57-CF56
Namuna	0.7050	23	2	CF57-CF56
Dangdunage	0.6741	24	1	CF57
Kalika chandika	0.6718	25	1	CF57
Rani	0.6715	26	2	CF57-CF56
Balkumari	0.6662	27	1	CF57
Bajrabarhi	0.6491	28	1	CF57
Kalika	0.6418	29	1	CF57
Baluwabharreng	0.6400	30	1	CF57
Kalika hariyali	0.6319	31	1	CF57
Mangleshar	0.6281	32		
Parbati mahila	0.6182	33		
Siddhakali	0.6135	34		
Kalabanzar	0.6116	35		
Lother	0.5990	36		
Newreni chisapani	0.5961	37		
Sundar	0.5759	38		
Laljhadi	0.5634	39		
Soltu	0.5566	40		
Dovan khola	0.5451	41		
Dipat	0.5409	42		
Bansgopal	0.5388	43		
Patleshar	0.5203	44		
Bungdal	0.5103	45		
Banaskhandi	0.4896	46		
Navalpur sarswati	0.4775	47		
Chhanauta	0.4723	48		
Chakradevi	0.4700	49		
Kalilek	0.4587	50		
Saradidevei	0.4421	51	4	CF1-CF4
Simpani devkot	0.4115	52	8	CF1-CF8
Bhutan devi	0.3923	53	11	CF1-CF11
Ektare	0.3739	54	12	CF1-CF12
Manakamana(Manahari)	0.3564	55	16	CF14-CF16, CF1-CF13
Dhaneshwar	0.3250	56	24	CF26, C1-CF23
Gosaikunda	0.2942	57	31	CF1-CF27

Note: PE= Production efficiency