Determinants of Rice Variety Diversity on Household Farms in the *Terai* Region of Nepal

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Abstract

Crop genetic resources are the building block of sustainable agricultural development as these can be used to develop crop varieties adaptable to heterogeneous environmental conditions. Nepal is considered the center of origin and diversity for Asian rice, which still has many landraces. However, there has been continuous loss of genetic diversity and concern over it has grown in recent years. The main objective of this paper is to identify the determinants of variety diversity on-farm in the rainfed ecosystem of Nepal by using two-limit Tobit procedure. The diversity on farm appeared to be quite high evaluated based on the number of named varieties grown by the farmers. Majority of the farmers cultivated both modern varieties and landraces simultaneously and the rice production is also getting commercialized gradually. The results showed that the motivating factors for variety diversification are the heterogeneous production environments, risk consideration and farmers' participation in the markets. However, the farmers' dependency on formal extension system for the seed of limited varieties led to reduction in diversity. Diverse crop genetic resources on-farm can generate both commercial and non-commercial benefits. As economies develop, markets play an important role in shaping farmers' choices and use of cultivars diversity. Therefore, the public investments are needed in developing the infrastructures to support the formation of niche markets and increasing the farmers' participation in crop breeding and improvement programs. Also, the formal extension system should be mobilized for the production and distribution of seeds of many varieties including the landraces.

Key words: diversity, market, Nepal, rice, variety

1. Introduction

Crop genetic diversity is the building block of sustainable agricultural development both in subsistence and technologically advanced societies. Genetic diversity allows farmers and plant breeders to adapt a crop to heterogeneous and changing environments. For several decades, concern over the loss of crop genetic diversity has grown, especially where a few, genetically uniform, high-yielding varieties have replaced genetically variable crop landraces (Brush 1991; Harlan 1992;Hawkes 1983; NRC 1993). This concern is especially relevant in areas where diversity is concentrated and where farmers maintain not only local seed of ancestral crop populations, but also the human knowledge and behavioral practices that has shaped this diversity for generations (Bellon et al. 1997; Brush 1991).

The available literatures reveal that there are different factors that motivate farmers to diversify the portfolio of their variety and crop choice. The possible factors under play are market orientation or subsistence, income diversification, heterogeneity of farmers' land resource, resource endowment (education, labor, and wealth), multiplicity of farmers' concerns (livestock ownership, taste, risk, labor shortage, wealth) and the impossibility to address them with a single variety. A change in any single economic factor is unlikely to cause farmers to change their variety and crop choice behavior (Smale et al., 1994; Meng et al., 1998).

In Nepal, rice is grown in all agro-ecological zones from the Terai (100-300m), through the valleys and foothills (100-1000 m), to the high mountains (2,600 m). Double cropping of rice ceases at around 900m, and rice reaches its altitudinal limit at 2,600 m. Few countries have such a diversity of both cultivated and wild relatives of rice (Gupta et al. 1996). Nepal is located in the area of origin and diversity for Asian rice, which has over 1,700 landraces of rice. NARC (1991) reported that genetic diversity has been maintained in the remote Karnali areas (mountains) where as the level of genetic erosion was the highest in the Kapilvastu and Banke districts in the Terai region.

Rice is the main staple food of Nepal. This crop is cultivated in about 15 million hectares and contributes more than 40 percent to the total calorie intake. In Nepal, the area under MVs has increased from about 40 percent in 1993/94 to about 83 percent in 2003/04 (MOAC, 2004). Compared to other ecological regions, this proportion is higher in Terai region where irrigation, roads and market infrastructures are well developed. Many farmers in Nepal cultivate several varieties of rice in a year in their farm.

The main objective of this paper is to identify the determinants of variety diversity on-farm in the rainfed ecosystem of Nepal. The analysis is motivated by the theory of the household farm applied to variety choice by constructing the variety diversity index. The agro-hydrological condition of the farm, socio-economic characteristics of the household, economic and market forces and farmers' preferences are considered to be important determinants of the diversity. The paper is organized as follows - The conceptual approach is presented in Section 2 while empirical estimation technique is presented in section 3. Section 4 presents the sampling and data collection technique while section 5 discusses the empirical results. The paper ends in section 6 with conclusions and implications.

2. Conceptual approach

Many approaches to modelling adoption found in literature on seed demand and seed adoption tend to assume separability between household production and consumption decisions (Feder, et.al, 1985 and Feder and Umali, 1993). Early theoretical models centered on maximizing expected utility of profits under risk, uncertainty, and learning-by-doing, emphasized the production side of farmer decisions (e.g., Hiebert, 1974; Smale et al., 1994). This is a sensible approach for analyzing commercially oriented farm decisions in competitive markets. Notably, in the economics literature of the green revolutions, subsistence production was treated through safety-first algorithms (Bell, 1972; Roumasset et al., 1979). The risk motivations have been revisited conceptually in the recent years (e.g., Marra et al., 2003). A rapid review of adoption studies over the past decade reveal few new theoretical constructs, other than the application of social learning concepts, for modelling farmer adoption of seed technology in developing countries (e.g., Conley and Udry, 2001). For semi-subsistence producers facing imperfect markets the theoretical context of a non-separable farm household model is appropriate.

Farmers in the Terai region of Nepal produce and consume both landraces (LRs) and MVs of rice. Their decision about which varieties of rice to grow and how much area to allocate for each variety can be explained by the theory of the household farm (Singh et al., 1986). In this theory, the household farm maximizes utility over a set of consumption items generated by the set of varieties it grows (C_f), a set of purchased consumption goods (C_{nf}), and leisure (l). The utility a household derives from various consumption combinations and levels depends on the preferences of its members. Preferences are in turn shaped by the characteristics of the household, such as the household size or education of its members, and wealth status. Choices among goods are constrained by the full income of the household, total time (T) allocated to farm production (H) and leisure (l), and a fixed production technology represented by $F(\bullet)$. The production technology combines purchased inputs (X) and labor (L) with the agro-hydrological characteristics of the farm (φ_F), which are fixed in a single decision-making period. Expenditures cannot exceed the value of all purchased goods, farm production and leisure. Full income in a single decision- making period is composed of the net farm earnings (profits) from rice production (Q_f), of which some may be consumed on farm and the surplus sold, and income that is ''exogenous'' to the year's variety choices, such as stocks carried over, remittances, pensions, and other transfers from the previous year (Y).

$$\max_{C_f, C_{nf}} U(C_f, C_{nf}, l; \varphi_{HH}) \quad (1)$$

s.t.

$$Q_f = F(X, L \mid (\varphi_F) \quad (2)$$

$$T = H + l \quad (3)$$

$$P_f (Q_f - C_f) - p_x X - wL + Y = P_{nf} C_{nf} + wH \quad (4)$$

When all relevant markets function perfectly, farm production decisions are made separately from consumption decisions. The household maximizes the net farm earnings subject to constraints and then allocates these with other income among consumption goods. Farm production decisions, such as crop variety choices, are driven by net returns, which are determined only by wage, input and output prices (w, p_f and p_x) and agro-hydrological characteristics of the farm (represented by vector φ_F).

The production and consumption decisions of the household cannot be separated when labor markets, markets for other inputs, and outputs are imperfect. Then, prices are endogenous to the farm household and affected by the costs of transacting in the markets. The specific characteristics of farm households (represented by vector φ_{HH}) and accessibility to markets (represented by vector φ_M) influence the magnitude of transactions costs and hence, the effective price governing the household's choices. If the land constraint for crop production also binds ($A = A^0$) so that farmers cannot change the total land area they cultivate in each growing season, the consumption goods produced on farm map into variety area shares through physical input-output relationships between goods, crops, and varieties (Smale et al., 2001). That is, at any point in time, each unit of seed of a crop or variety generates an expected level of output to sell or consume, based on the germplasm it embodies, inputs applied in its production, and physical growing environment. The objective function in (1) can then be expressed as:

$$\max V(C_f, C_{nf}, l; \varphi_{HH}) \quad (5)$$

$\alpha_i \ldots \alpha_n \geq 0$

where the choice variables are area shares (α) planted to varieties i = 1,2, .,n. The reduced form equation (6) expresses optimal area among varieties as functions of a vector of prices, farm size, exogenous income, and vectors of farm household, farm physical, and market characteristics.

$$\alpha^* = \alpha^*(p, A^0, Y, \varphi_{HH} , \varphi_F , \varphi_M) \quad (6)$$

Variety Diversity Index is constructed from the area shares, as described in the next section. Reduced form equations estimated econometrically take the following conceptual form, as in Van Dusen (2000) and used by Benin (2003).

$$d = d (\alpha^*(p, A^0, Y, \varphi_{HH} , \varphi_F , \varphi_M) \quad (7)$$

3. Empirical estimation

In this paper, the variety diversity means the crop populations that farmers recognize and name as distinct units. It is basically a diversity of name rather than genetic or trait based definition of varieties. This view of variety diversity is an incomplete one as farmers might have given different names to the genetically same population or variety. However, those were the varieties that farmers recognized, controlled and acted upon.

In order to identify the factors determining the level of diversity, quantitative indicators of variety diversity and environmental differentiation are needed. The Herfindahl index (HI) of spatial diversity has been used to represent variety diversity. HI[1] is the sum of squared shares of area planted to each variety, which is essentially the weighted average of the proportional area of each variety, with the weights being the shares themselves. A modified HI is used for this analysis. A Varietal Diversity Index (VDI) for a farmer is defined as one minus the sum of squares of the proportional area planted to each variety. It is calculated as

$$VDI_j = 1 - \Sigma_j (\alpha_{ij}/ A_i)^2 \quad (8)$$

[1]Herfindahl index : $h = \Sigma_j (\alpha_j/\Sigma_j\alpha_j)^2$

where α_{ij} is the area planted to the j^{th} variety by the i^{th} farmer and A_i is the total rice area planted by the i^{th} farmer. The index is zero for a farmer growing only one variety and approaches unity as the level of diversity increases.

Farmers in the rainfed areas tend to grow several varieties simultaneously for several reasons. First, variety diversity can result from farmers' attempts to match varietal characteristics with the niches (Brush et al., 1981, Richards 1986, Lando and Mak, 1994). Second, varietal diversification may be a method of reducing risk (Feder et al. 1985, Anderson and Hazell, 1994). By not putting ' all eggs in one basket', variety diversification can help reduce the yield risk. Third, diversification can help avoid labor bottlenecks in planting, weeding, and harvesting (Richards, 1986). By growing varieties of different durations, farmers can stagger the labor demand and make more effective use of family labor. Finally products from different varieties may be appropriate to satisfy a range of demands. Variety diversification could be an effective strategy of obtaining a range of products when there are variety differences in product attributes.

To the extent that matching the variety requirement to a specific environmental niche is also a reason for variety diversification, a farmer with more diverse environmental conditions may be expected to grow a greater number of varieties. Niche matching has been considered to be a major reason for variety diversification in maize (Bellon and Taylor, 1993). To examine this hypothesis, farmers were divided into groups operating within one or more sub-ecosystems as defined by farmers. Farmer classification of soil and land types has been found to be highly correlated with scientific soil classification (Bellon and Taylor, 1993, Talwar, 1996). As a first step, farmers' classification of upland, medium land and lowland has been used as the basis for sub-ecosystem classification. Within each sub-ecosystem, the farmer classification of soil types such as clay, clay loam, sandy and sandy loam has been used.

Niche index (NI) for the i^{th} farmer is defined as one minus the sum of squares of the proportional area under the k^{th} soil type and l^{th} land type as used by Kshirsagar et al. (2002). More specifically, NI is calculated as

$$NI_i = 1 - \sum_{l\,k} (\alpha_{ikl} / A_i)^2 \qquad (9)$$

where α_{ikl} represents the area with k^{th} soil type and l^{th} land type for the i^{th} farmer. Like VDI, the niche index is zero for a farmer with only one soil type and only one land type and approaches unity as the diversity of niche increases.

In addition to environmental diversity, there may be socio-economic factors such as risk reduction or desire to have stable production, staggering of labor demand and product diversity that determine the desired level of variety diversity. Labor supply, measured here by the number of workers between the ages of 15 to 59 years, can influence the level of diversity in two ways. First, more labor may be required to 'manage' different varieties. Threshing of different varieties needs to be done separately and the seeds have to be selected and kept separately. If different varieties have to be managed differently in the field, this will increase the time required for monitoring the crop conditions and implementing the decisions. Second, if staggering of labor demand were a major reason for diversity, the number of varieties grown would be expected to decline with an increase in labor supply. A priori, the effect of family size on the level of diversity is, hence, ambiguous.

The size of the operational holding (or land holding) is hypothesized here to be another variable that can influence the extent of variety diversity, although the direction of effect is ambiguous, a priori. Farmers with larger operational holding may be less risk averse and hence may lack incentives to grow more varieties for risk reduction. Risk aversion is expected to be negatively correlated with wealth (Arrow 1970), which in rural societies is mainly agricultural land. Thus, diversity may be negatively correlated with the farm size. In addition, larger farmers may be more inclined to grow more number of varieties to ensure the supply of a range of rice products for farm labor, friends, guests and relatives as a result of their higher social status in rural communities.

Also due to the existence of imperfect markets, farmers may grow different varieties to meet their consumption requirement such as taste and fodder for livestock as a straw. Farmers may also sell some of the grains to the market so as to buy their family needs (clothes and other goods/commodities). This may motivate farmers to grow the varieties that can be sold in the market for cash. The definition of these variables, the specific measures used and their expected effect on diversity are summarized in Appendix 1. The observed VDI values were greater than or equal to zero and less than or equal to one but predicted values may lie outside that interval. To correct for that problem, the reduced form equation (7) was estimated by two-limit Tobit procedure.

4. Survey and data collection

The present study is based on the sample survey of variety choice of 222 rice farmers from two districts of Terai of Nepal. The farmers were selected from 3 rainfed villages of each districts using stratified random sampling.[1] The villages where survey was carried out are Manikapur, Bethani and Bageswori from Banke district (mid – western development region) and Kushma, Deurali and Ramnagar villages from Nawalparasi district (western development region).

The survey included collection of data on number and types of rice varieties grown, varieties replaced in the last five years, seed sources, and associated socio-economic and demographic characteristics. The relevant data for the cropping year 2001/02 were collected through personal interviews using a set of pre-tested questionnaires.

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[1]The Terai is a southern plain region of Nepal which borders with India.

5. Results and discussion

5.1 General characteristics of rice production system

The basic characteristics of the production systems in the two sampled districts are summarized in Table 1. The average farm size is much larger in Banke than in Nawalparasi. While rice is the dominant crop in both the locations, the share of MV was higher in Banke than in Nawalparasi. The cropping intensity and the proportion of irrigated area are higher in Nawalparasi than in Banke.

5.2 Description of the varieties grown

Evaluating by the number of named varieties being grown by the farmers, the variety diversity in the study area appeared to be quite high. The sample farmers grew as many as 25 MVs and 19 LRs. About 10 percent farmers grew only one variety in the study area. Most of the farmers grew more than one rice variety on their farms, with a number of varieties ranging from one to nine. The percentage of farmers growing two to three varieties was about 72 percent (Table 2). Also about 52 percent households grew both modern varieties and landraces. About 39 percent of the farmers grew only MVs whereas about 9 percent grew only LRs. (Appendix 3).

5.3 Quantitative analysis of variety diversity

To test the relationships outlined in the theory, Tobit regression model has been estimated. The results are presented in Table 3. The goodness of the fit of the model is judged by the likelihood ratio (LR) test and pseudo R^2. The LR statistic was found highly significant implying that the independent factors, when taken together influenced the variety diversity. The pseudo R^2 was 0.4 indicating about 40 percent of the variations in the VDI is explained by the included explanatory variables.

Most of the results confirm a priori expectations. The main factor determining the degree of variety diversification is the niche index (NICHES). The positive and highly significant coefficient of NICHES indicates that the farmers have planted more number of varieties with diverse environmental conditions. The risk consideration of the farmers has contributed to the variety diversity. Due to the predominance of the rainfed ecosystem, the farmers have preference for maintaining the stability of production, hence grow more number of varieties. This is indicated by the very highly significant coefficient of the PRODSTAB.

There was a strong correlation between the size of landholding (LANDHOLD) and the percentage of the total production marketed. Hence, to avoid multicollinearity, only the PCMARKT has been used. The farmers with bigger size of land holding grow more number of varieties to meet their special needs. They also sell the product in the market which increases the with the size of land holding. It means those farmers who are participating in the markets for the sale of output, would like to grow more number of varieties with the rice variety type demanded in the markets. Like that mentioned by Gauchan et al. (2001), farmers who participate in the market are more likely to grow LRs and MVs simultaneously, thus increasing the diversity (Also see Appendix 3). Farmers' dependency on the formal seed source reduces the number of varieties grown on farm as indicated by the negative significant coefficient of the SEEDSOU. This is true that the formal seed distribution system especially the extension system of Nepal focuses more on the seed production and distribution of limited MVs. But there are no formal sector seed activities in case of traditional varieties.

The other factors positively associated with the variety diversity were straw as a fodder for livestock, number of working members between the age of the 15 to 59 years in a family, farmers' perceptions on the shortages of labor especially during harvesting time, and preference for taste of rice. The factors that may contribute towards low variety diversity were area under year round/controlled irrigation, education level of the household head and sources of non-farm income. However, the coefficients of all of those variables were not significant.

6. Conclusion and policy implications

The variety diversity in the study area appeared to be quite high. Also, the rice production is gradually commercializing as about 70 percent of farmers sell their produce. About 53 percent of the households continue to grow both modern varieties and landraces simultaneously. Their demand for these types is clearly shaped in part as a derived demand from markets, land and soil heterogeneity and in part by the consumption preferences of their families.

In the Terai region of Nepal, the most motivating factors for variety diversification are land heterogeneity, risk considerations, and market participation. Farmers' concerns such as need of fodder for livestock, perception of the shortage of labor during planting and harvesting season, preference for taste and household labor availability are also associated with the variety diversity. The dependency of farmers to limited seed varieties from formal extension system, availability of the year rounds irrigation and non-farm jobs do not motivate the farmers to maintain diversity on-farm.

Diverse crop genetic resources on farms can generate multiple types of benefits, including commercial and non-commercial benefits. Hence, there is a need to conserve on-farm diversity as part of a strategy to conserve crop genetic resources. As economies develop, markets play an important role in shaping farmers' choices and use of cultivars diversity. Therefore, the public investments are needed in developing the infrastructures to support the formation of niche markets and increasing the farmers' participation in crop breeding and improvement programs. Also, instead of confining the seed production and distribution to limited number of varieties, large number of varieties including landraces should be promoted by utilizing the existing extension network.

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Table 1. General characteristics of the production systems in the study area

FEATURES	DISTRICTS	
	Banke	Nawalparasi
Average area owned per household (ha)	2.3	1.1
Cropping Intensity (%)	151	185
Area under rice (% of total cropped area)	53	52
Area under MV of Rice (%)	81	73
Average Yield of MV (t/ha)	3	3
Average Yield of LR (t/ha)	1.6	2.3
Percentage Area Irrigated (including seasonal)	35	72

Table 2. Percentage of farmers growing one or more varieties of rice in the study area

NO. OF VARIETIES	PERCENTAGE DISTRIBUTION		
	Banke	Nawalparasi	Total
One	12.4	8.3	10.4
Two	40.7	41.3	41.0
Three	29.2	33.0	31.1
Four	12.4	12.8	12.5
Five and above	5.3	4.6	5.0

Table 3. Determinants of rice varietal diversity.

VARIABLES	MARGINAL EFFECTS	STANDARD ERROR
Constant	0.0576	0.0680
NICHES	0.6420***	0.0741
PRIRRIG	-0.0519	0.0434
PCMARKT	0.00182***	0.0006
WORKER	0.0037	0.0059
EDUC	-0.00018	0.0033
LIVESTOK	0.0077	0.0092
PRODSTAB	0.1308***	0.0400
PLABOR	0.0391	0.0281
PTASTE	0.00015	0.00015
INCOMSOU	-0.00009	0.00008
SEEDSOU	-0.0787**	0.0317
Likelihood Ratio	98.96***	
Pseudo R^2	0.40	

Note: *** and ** indicate significant at 1 percent and 5 percent level, respectively.

Appendix 1. Definition of the variables included in the econometric study of varietal diversity

Variable	**Definition**	**Measurement**	**Expected sign**
NICHES	Niche Index considering land and soil types.	Index	positive
EDUC	Educational attainment of decision maker	No. of years of schooling	unpredictable
WORKER	Number of workers in the household between 15 to 59 years of age	Number	positive
PRIRRIG	Area irrigated (year round)	Percentage	negative
LIVESTOK	Livestock population in a household	Number	positive
LANDHOLD	Size of the land holding	Hectares	unpredictable
PCMARKT	Marketed quantity of rice	Percentage	positive
PRODSTAB	Preference of the farmer to maintain production stability	Binary; 1= if the preference for production stability is important, 0 = otherwise	positive
PLABOR	Perception of the farmer regarding the shortages of labor during planting and harvesting seasons.	Binary; 1= if farmer perceives shortages of labor, 0 = otherwise	positive
PTASTE	Preference of the farmer for taste attribute	Binary; 1= if the preference for taste attribute is important 0 = otherwise	positive
INCOMSOU	Income sources outside agriculture	Binary; 1= if some family members is involved in off-farm activities.	negative
SEEDSOU	Sources of seed	Binary; 1= if from formal sources 0 = otherwise	unpredictable

Appendix 2. Some descriptive statistics of the variables used in econometric analysis

Variables	Banke	Nawalparasi
Quantity of Rice Marketed (% of total production)	24.45	26.18
Percentage of Households selling	72.6	68.8
No. of work ers between 15 to 59 years of age(per household)	4.58	4.64
Household size (persons)	8.26	7.55
Education level of Household head (No. of years of schooling)	4.03	3.78
No. of Livestock per household	3.55	2.86
Varietal Diversity Index	0.41	0.49
Niche Index	0.51	0.41

Appendix 3. Rice types grown by farmers, by their market participation, in Banke and Nawalparasi disticts, Nepal.

Descriptions	Rice sellers (n = 157)	Non-sellers (n = 65)	All Households (n = 222)
Growing traditional varieties only	7.6	12.3	9.0
Growing modern varieties only	34.4	50.8	39.2
Growing both modern varieties and landraces	58.0	36.9	51.8
Mean Among Farmers			
No. of landraces grown	0.89	0.60	0.82
No. of modern varieties grown	1.96	1.45	1.81
No. of total varieties	2.85	2.05	2.63
Percentage of rice area in landraces	24.3	20.1	23.0
Percentage of rice area in modern varieties	75.7	79.9	77.0