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Recent Adoption and Spatial Diversity of Modern Rice Varieties in the Philippines

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Abstract

This paper provides updated information on rice (*Oryza sativa* L.) variety adoption trends in the Philippines using three sets of surveys of nationwide rice farm households. It also presents some assessments of the adoption rates of newly released varieties and calculated spatial diversity indices for rice. In 2003, the area planted with modern varieties was almost 100% in both the irrigated and rainfed areas. The aggregate measure of the replacement period for rice varieties in the farmers' fields is around 8 to 11 years, with the fastest adoption rate during the dry season in irrigated areas. The spatial diversity indices show no clear trend across periods except for a relative increase in the coefficient of variation of the indices, and greater variability across provinces in richness, relative abundance and evenness. There are some indications, however, of relatively increasing richness and lowering dominance especially during the dry season when farmers try more new varieties.

Key words: rice, variety adoption, spatial diversity, genetic diversity, Philippines

Introduction

Although the Philippines was one of the earliest adopters of "green revolution" seeds and fertilizer technologies, and in 2003, the area of the country planted to modern varieties (MVs) was almost 100% in both irrigated and rainfed areas, the country is still not self-sufficient in rice. From 1990 to 2005, yield grew by only 1.6% per year leading to slow production growth, while the population growth rate continues to grow by more than 2% yearly (PhilRice, 2005: Figure 1). Thus, rice researchers

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continue to ensure stable and sustainable rice production through the development of high yielding, pest and abiotic stress resistant and good grain quality rice varieties. To date, since 1968, 138 MVs have been released -- 92 for irrigated, 19 for rainfed, 13 for upland, 6 for cool-elevated, and 8 for saline-prone rice areas in the Philippines. These varieties are grouped into four generations based on the dates of release and their distinct characteristics (Estudillo *et al.,* 2006). The MV first-generation (MV1) consisting of the IR series from IR5 to IR34 developed by IRRI and the C4 series developed by UPLB were released from the mid-1960s to the mid-1970s. MV1 was potentially higher yielding than traditional varieties (TVs) under ideal conditions but more fertilizer responsive than TVs because it was short in stature with stiff straws that enabled it to bear more grains. The MV second-generation (MV2) consisting of IR36 to IR62 was released from the mid-1970s to the mid-1980s. MV2 was designed to ensure yield stability by incorporating resistance to multiple pests and diseases. The MV third-generation (MV3) consisting of IR64 to IR72 and PSBRc2 to PSBRc74 was released from the mid-1980s to the mid-1990s. MV3 incorporated better grain quality and stronger host plant resistance. The MV fourth-generation (MV4) were released after 1995 and especially developed for production in adverse environments. Hybrid rice varieties are also being developed under the national program for hybrid rice commercialization and are now being adopted (Casiwan *et al.,* 2007).

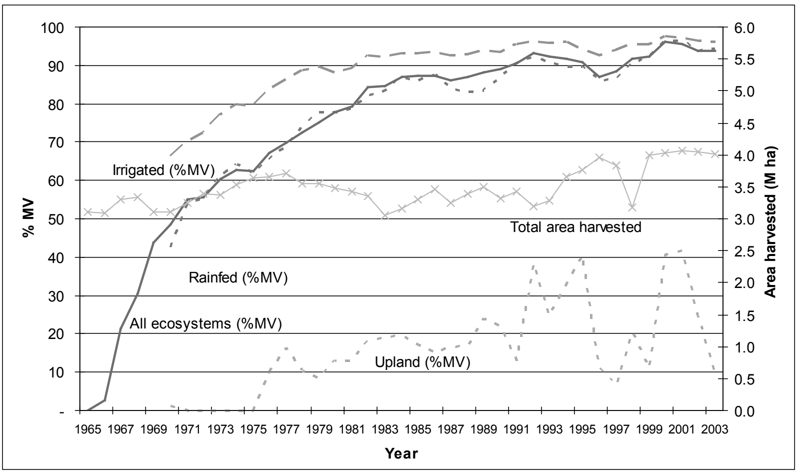

Fig. 1. Trends in MV area harvested, 1965 to 2002, The Philippines

Several studies have documented the rapid adoption of MVs over the period from 1968 to the 1980s (David *et al*., 1994; Herdt *et al*., 1983). Not much data, however, have been publicly available on more recent time periods, especially about the development or diffusion of new rice varieties from the 1990s. A recent study assessed the changing contributions of successive generations of modern varieties (MVs) of rice to yield increase and stability and changes in total factor productivity (TFP) in the Philippines (Estudillo *et al.*, 2006), but this study used adoption data only from Central Luzon, Philippines, and secondary data in which the use of specific MVs can not be distinguished.

In addition, plant breeders justify the continuous breeding and release of varieties as a means to promote genetic diversification which can contribute to the sustainability of rice production growth in the future. Genetic diversity is known to substantially reduce a crop's vulnerability to diseases especially in tropical countries where there is staggered planting. Understanding the variety dispersal in the major rice producing regions of the country would indicate to some extent the genetic diversity of the rice crops being planted in the country.

This paper thus aims to (1) measure variety adoption rates of officially released rice varieties, particularly the later generation varieties, using three rounds of national rice-based farm household surveys (RBFHS); (2) present the spatial diversification of varieties planted in farmers' fields, and (3) draw policy recommendations from the results of the study.

1. Data and methods

1) Data used

The study used data from the RBFHS being conducted by the Socioeconomics Division (SED) of PhilRice every five years covering the 1992-93, 1996-97 and 2001-02 crop years. The RBFHS in 1992-93 covered 15 major rice-producing provinces with 977 respondents. The total rice area in these major rice-producing provinces comprise around 50% of the country's total rice area harvested. On the other hand, the 1996-97 and 2001-02 surveys covered 30 and 33 provinces with 2239 and 2474 valid respondents, respectively. The sum of the rice areas represented by the provinces covered in the 1996-97 and 2001-02 rounds is around 70% of the country's total rice area. Frequency of use of varieties by respondents, identification of oldest and newest varieties planted, and share to total area planted by variety were clarified using these cross-section data sets.

2) Analysis of adoption and spatial diversity

To better understand the dynamics of rice variety adoption, two indices such as the proportion of recent varieties and weighted average age of varieties were calculated to determine the adoption rate of the newly released varieties following Brennan (1984).

The proportion of recent varieties is estimated as the proportion of the total area that is planted with recently released varieties. This index, q_{it}, is computed as follows: $q_{it} = p_{it}$ if year of release $\geq t\text{-}m$, while $q_{it} = 0$ if year of release $< t\text{-}m$, where p_{it} is the proportion of the area sown with variety, i, in year, t; m is the number of years used to define "recent". Then

$$I_t = \sum_i q_{it}$$

where I is the proportion of the total area that is sown with varieties released in the previous m years. In this study, we assumed a lag of two years between the release of a variety and its availability to farmers, and defined 'recent' variety as a variety that is available to farmers for five more years, thus in this study we used m=7.

The weighted average age of varieties[3], on the other hand, consists of the weighted average age of varieties grown by farmers in a given year, measured in years from varietal release and weighted by the proportion of area sown with each variety at that time. This index, WA_t, is computed for a given year, t, as follows:

$$WA_t = \sum_i p_{it} R_{it}$$

where R_{it} is the age of the variety in terms of the number of years (at time t) since the release of variety i. This measure avoids the use of an arbitrary definition of "new" or "recent" varieties (Brennan *et al*, 1991).

Varietal diversity is presented in this study by determining the number of released varieties planted by farmers in a province in a given year and season, and by determining the variety groups planted by farmers (Estudillo *et a*l., 2006). The estimated proportion of area planted with only one or a few varieties in a province was also described to show the diversity in varieties planted.

For spatial diversity indicators, we employed three spatial diversity indices used by ecologists (Benin *et al*., 2004; Smale *et al*., 2003). Table 1 shows the concepts and mathematical formulae used in deriving the indices adapted from Smale *et al*. (2003) and applying them in the case of rice.

Table 1. Spatial diversity indices used

Index	Concept	Mathematical construction	Explanation	Adaptation in this paper
Margalef	Richness	D = (S-1)/ln N (D=>0)	Number of species (S) recorded, corrected for the total number of individuals (N) summed over species	S is the number of rice varieties grown in a season by the respondents, N is the total hectares of rice planted by the respondents in that season
Berger-Parker	Relative abundance or Inverse dominance	D = 1/(Nmax/N) (D=>1)	The more dominant the most abundant species, the lower the index value	Inverse of maximum area share occupied by any single rice variety
Shannon	Both richness and relative abundance	$D = -\sum p_i \ln p_i$ (D=>0)	The p_i is the proportion, or relative abundance of a species	The p_i is the area share occupied by the ith variety

Source: Magurran (1988) and Smale et al. (2003)

2. Results and Discussion

1) Adoption rate of newly released varieties

Table 2 shows the trends of varieties planted by variety group. Until 1997, there was still a significant percentage of farmers planting MV2 varieties which were designed to ensure yield stability by incorporating resistance to multiple pests and diseases. We can, however, see a trend of progression in the use of modern varieties—a decreasing trend in the use of MV2 and increasing use of MV4. From 1992 to 2002, MV3 varieties were widely used. The noted slight increase in the use of TVs was brought about by the commercial release of some local traditional varieties which have good performance and are popular selections among farmers.

The proportion of the total area planted with new varieties (varieties released in the previous 7 years from the time of survey) is on average around 30% to 40% of the total rice area in the country (Table 3). In the 1993 DS, for example, 37% of the

Table 2. Trends of rice variety planted by farmers (%), by variety group

Variety Group	1992 WS		1993 DS		1996 WS		1997 DS		2001 WS		2002 DS	
	IRR	RF	IRR	RF	IRR	RF	IRR	RF	IRR	RF	IRR	RF
MV1[a]	3.3	6.8	2.1	0.0	2.3	2.1	2.1	2.0	0.4	0.5	0.1	0.0
MV2[b]	29.2	31.0	27.1	70.0	12.2	20.3	12.0	15.7	4.6	9.0	4.1	3.3
MV3[c]	53.0	56.7	56.1	20.0	73.7	66.7	71.4	68.5	73.2	59.0	60.7	55.5
MV4[d]	0.1	0.2	0.2	0.0	0.8	0.5	1.3	0.7	7.3	10.4	18.8	14.7
Hybrid	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Masipag	0.1	0.7	0.0	0.0	2.7	2.5	3.3	2.7	4.8	7.4	5.1	9.7
Traditional	8.6	1.8	8.4	0.0	0.6	1.1	1.2	1.4	5.0	6.6	4.0	8.8
Unclassified	5.6	2.9	6.2	10.0	7.6	6.8	8.7	8.9	4.6	7.2	7.2	8.0

[a] *MV1 - IR series from IR5 to IR34; C4 series from the mid-1960s to the mid-1970s*
[b] *MV2 - IR36 to IR62 released from the mid-1970s to the mid-1980s*
[c] *MV3 - IR64 to IR72; PSB Rc varieties released from mid-1980s to mid-1990s*
[d] *MV4 - Varieties released after 1995*
Note: IRR - irrigated; RF - rainfed

irrigated (IRR) MV areas were planted with varieties released from 1986 to 1992. In 1997, varieties released from 1990 to 1996 covered more than 50% of the rice area planted during the DS, in the irrigated areas. PSB Rc10 and PSB Rc14, both released in 1992, and PSB Rc18, released in 1994, were widely used varieties in the 1996-97 cropping year. In 2002, new rice varieties occupied 24% to 36% of the rice area. When compared with the 1997 situation, the area is relatively lower because PSB Rc18, IR64, PSB Rc10, and Masipag varieties, none of which are 'new variety' per definition, dominated the farmers' fields. Province level analysis indicates that in 2002, most of the farmers still used varieties released before the 1997 period, even while new varieties occupied a significant portion of the rice area.

In the few rainfed (RF) DS areas, only 10% of the areas were planted with new varieties in 1992, but in the 1997 and 2002 surveys, 57% and 32% were planted with new varieties. These results imply that rainfed-rice farmers also adopt new rice varieties almost as much as the irrigated-rice farmers. Some farmers also use irrigated varieties in the rainfed areas probably because there are only a few rainfed varieties and the WS in favorable rainfed areas is almost similar to an irrigated ecosystem. However, the same surveys showed that more farmers in the irrigated areas (21%) use certified and good seeds compared with rainfed farmers (10%). In 2002, 28% of the farmer-respondents in irrigated areas adopted certified seeds or better, compared with only 17% in the rainfed areas. It is possible that farmers in the rainfed rice areas buy

Table 3. Indices of adoption rates of new varieties, by season and farm type, The Philippines

Year/ Season	Eco-system[t]	No. of released varieties planted[a]	Proportion sown to recent varieties[b] (I_t:%)	Weighted average age of varieties[c] (WA_t:yr)	Most recent variety used		Oldest variety used	
					Variety	Year released	Variety	Year released
1992 WS	Irrigated	39	32.89	8.92	PSBRc6, -10,-12	May, 1992	IR8, C4-63G, BPI76	1968
	Rainfed	37	20.10	9.90	PSBRc2, -4	Nov., 1991	IR8,-5, C4-63G, BPI76	1968
1993 DS	Irrigated	34	37.01	8.31	PSBRc8, -10,-12, -14	May, 1992	IR8, C4-63G, BPI76	1968
	Rainfed	8	10.28	14.27	IR72	1988	IR36	1976
1996 WS	Irrigated	53	51.38	8.93	PSBRc5, -54,-56, -60	Nov. 1997	IR20	1969
	Rainfed	45	43.45	10.09	PSBRc3, -5,-60,-72H	Nov. 1997	IR20	1969
1997 DS	Irrigated	49	54.71	8.41	PSBRc3, -5,-54,-60	Nov. 1997	IR20	1969
	Rainfed	38	57.40	8.76	PSBRc5 , -60, -68	Nov. 1997	IR20	1969
2001 WS	Irrigated	47	23.52	10.81	NSIC Rc122, PSB Rc 90, -94	Dec. 2003, Jan., 2001	BPI Ri3	1973
	Rainfed	49	28.88	11.20	PSB Rc 90/ -94	Jan., 2001	IR29, IR32	1975
2002 DS	Irrigated	54	35.97	9.50	PSBRc90, -94,-98, -100	Jan., 2001	IR29, IR32	1975
	Rainfed	49	32.01	10.21	NSIC Rc 122,PSB Rc 94, -100	Dec. 2003, Jan., 2001	IR42	1977
AVERAGE OF 3 SURVEYS								
WS	Irrigated		35.93	9.55				
	Rainfed		30.81	10.40				
DS	Irrigated		42.56	8.74				
	Rainfed		33.23	11.08				

[a] *This is the total number of released varieties mentioned by farmers. This does not include varieties which are not released by the Philippine seed board or now, the National Seed Industry Council, such as the Masipag varieties or other selections or lines; traditional varieties; or farmer-selections or farmer-named*

[b] *Proportion of recent varieties is an index showing the proportion of the area planted to varieties released in the previous seven years*

[c] *Weighted average age of varieties is an index of the average age of released varieties grown by farmers, measured in years from varietal release and weighted by the proportion of area sown to each variety*

or exchange new varieties from co-farmers who are in irrigated areas, where there is widespread promotion of the use of certified seeds through the national rice program.

Using the weighted average age of varieties as an index of the adoption rate of new varieties revealed higher adoption during the DS in irrigated ecosystems. The weighted average age of varieties planted in the country ranged from around 8 to 11 years, with the average age in the irrigated areas during the DS at 8 to 9 years. This relatively consistent trend based on the three sets of cross-section data implies that varieties in farmers' fields in general are replaced every 8 to 11 years, faster in the irrigated areas during the DS. In the 1997 survey, the average age of varieties planted in a majority of the provinces were less than 10 years in both seasons, while in the 2002 survey, it was 10 years or more. This confirms the above observation that although some farmers planted new varieties, most of the rice areas in 2002 were planted with varieties released prior to 1997.

The information on the oldest and newest varieties used show two things. First, some farmers still plant varieties released more than 20 years ago. In 1997, a few farmers in various provinces still planted IR20, an early modern variety bred for insect and disease resistance released in 1969. It was reported not only by farmers in Luzon, but also in provinces in the Visayas and Mindanao which are far from the primary source of seed materials. In 2002, some farmers still planted varieties released in 1975 such as IR29 and IR32, and many farmers planted IR42 released in 1977. The IR42 variety endures generally because of its good grain quality and it still commands premium price in the market.

Second, the information on the newest variety planted shows that farmers do use new varieties suggesting that the current extension system (use of seed network, tri-media and technology-demonstration farms) for varieties is apparently functioning. For example, in the 1992 WS, 5% of farmers in the major rice-growing provinces already planted the varieties PSB Rc2 and PSB Rc4, which were released only in Nov. 1991. This is only one season after their release. In the case of PSB Rc10, PSB Rc12 and PSB Rc14, all of which were released in May, 1992, almost 2% of farmers were planting these varieties by the 1993 DS including PSB Rc6 and PSB Rc8 varieties. In November 1997, several newly released varieties were already used by some farmers in the 1996 WS and 1997 DS. This is possible because there were varieties recommended and submitted for seed increase although their official approval was delayed. In the

2001 WS, some farmers reported planting the newest varieties, namely: PSB Rc90, PSB Rc94 and NSIC Rc122 released only in January 2001.

2) Variety diversification and spatial diversity indices

Table 4 shows the spatial diversity indices calculated based on the household surveys. The ranges of the spatial indices show differences in terms of spatial diversity of rice varieties across provinces, but not so much across periods. There are some provinces where the Margalef index-number of varieties per unit of area is less than one while there are provinces where the index is as much as 6 to 7. Although relatively speaking, the diversity of the rice variety planted by farmers increased from the 1992-93 to the 1996-97 period, there is no marked change from the 1996-97 to the 2001-02 crop periods. This means that even with the greater number of varieties from which farmers can choose, the number of varieties planted in the farmers' rice area at any one period does not vary much. This suggests that there is in a way a bandwagon effect in farmers' variety-use where certain preferred varieties planted by one farmer are also planted by other farmers. Varieties that perform well in farmers' fields and command a higher price in the market based on hands-on experience tend to endure. This also reinforces what has been mentioned earlier; that rice farmers when given more variety

Table 4. Descriptive statistics for indices of the spatial diversity of the rice varieties grown in major rice growing provinces of the Philippines, 1992-2002

Diversity Index/ Statistics	Season/Year					
	1992 WS	1993 DS	1996 WS	1997 DS	2001 WS	2002 DS
Margalef Index						
M	3.01	2.21	3.90	3.61	3.58	3.75
SD	1.61	1.10	1.16	1.09	1.25	1.30
Min	1.48	0.75	1.04	1.44	0.48	0.71
Max	7.03	3.82	5.87	5.25	6.01	5.97
Berger-ParkerIndex						
M	2.60	2.74	4.25	4.37	3.52	4.44
SD	0.97	0.82	1.95	1.69	1.66	3.45
Min	1.15	1.19	1.51	1.88	1.02	1.13
Max	4.21	4.33	8.13	8.82	8.50	9.13
ShannonIndex						
M	1.85	1.77	2.19	2.19	2.05	2.13
SD	0.53	0.43	0.41	0.39	0.50	0.52
Min	0.59	0.56	1.19	1.26	0.13	0.46
Max	2.72	2.24	2.85	2.71	2.85	2.93

options replace the variety planted, without necessarily increasing the number of varieties planted at one time.

In terms of the index of whether or not certain species dominate others, the Berger-Parker index ranged from as low as 1.02 (the case of Davao Oriental, where the IR64 quality is distinct and demanded by consumers so that almost 98% of the total area was planted with IR64) to as high as 8.5 (the case of Laguna province, which is located near IRRI, where as many as 26 different rice varieties were planted in a total of 64 hectares sampled. This range and the relatively large standard deviation especially in the 2002 DS indicate wide variability in the extent to which one variety dominates in a given area. The Berger-Parker Index overall mean though is relatively low considering the total number of commercially released varieties, implying that selected preferred rice varieties indeed dominate the farmers' fields. The Berger-Index showed a lowering of dominance between the 1992-93 and 1996-97 periods, but no consistent trend from the 1996-97 to 2001-02 periods. Decreased dominance is also evident during the DS which suggests that farmers are probably trying more varieties during the less risky DS. Farmers try new varieties during the DS because it is less vulnerable to pests and diseases and the optimum yield can be better expressed.

The wide difference in the diversity index across provinces is also reflected in the calculated Shannon index--for example, both close to zero (0.13) and a maximum of 2.85 in the 2001 WS. A close to zero Shannon index means that the area share distribution of the varieties is not even. The mean Shannon index has not significantly changed from the 1996-97 to 2001-02 periods although there is an observed slight decrease implying a less even area share distribution.

Conclusion

The main contribution of this paper is to document and describe, using three sets of nationwide farmers' surveys, the recent adoption of rice varieties in farmers' fields, especially the later generation varieties. Data showed a progression in the use of MVs from the early to the later generations evident from the decreasing trend in the use of MV2s and the increasing trend in the use of MV4s. This information can be used to encourage policymakers to continually support and strengthen the current efforts of public rice breeding research and extension. One observation is that the proximity of the rice area to the source of original seeds has an effect on the current state of morphological diversity and that farmer to farmer learning is a strong factor for this. Thus, it is important that the current provincial variety adoption rates and diversity be taken into account when planning for variety testing and promotion. Variety monitoring is important and should be considered as part of the mandate of the Bureau of Agricultural Statistics (BAS) which conducts quarterly surveys of rice-based farmers.

Regarding variety diversification, the three cross-section data showed that around 70% to 80% of the rice areas in the country are planted with only 10 different varieties in a given period, the majority of which are varieties released more than five years before the survey period. The spatial diversity indices implied that there are relatively wide differences in diversity across provinces but not so clear trends across periods. There is an indication of a relative increase in richness and lower variety dominance in the DS, but there is no sufficient evidence of significant changes in spatial diversity. This suggests that the continued development of varieties may be maintaining the current morphological diversity in farmers' fields. The data, however, is only quinquennial which limits more trend analysis of diversity and variety replacement. Further studies on the exact genetic diversity of varieties in farmers' fields considering parentage, and on the determinants of the spatial diversity will be necessary for biodiversity conservation purposes. Further analysis of the relationship between spatial diversity and vulnerability to pests and diseases is also recommended.

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