ISSN 1479-2621
Plant Genetic Resources: Characterization and Utilization (2008); 1–9
doi:10.1017/S1479262108060930

Recent changes in varietal diversity of rice in Guinea

M. B. Barry[1], A. Diagne[2], M. J. Sogbossi[2], J. L. Pham[3], S. Diawara[1] and N. Ahmadi[4]*

[1]*Institut de Recherche Agronomique de Guinée, BP 1523, Conakry, Guinea,* [2]*WARDA, BP 2031, 01 Cotonou, Benin,* [3]*UMR DGPC/IRD, Av Agropolis, 34398 Montpellier Cedex 5, France and* [4]*CIRAD, Av Agropolis, 34398 Montpellier Cedex 5, France*

Received 7 June 2006; Accepted 24 July 2008

Abstract

Rice varietal diversity was assessed in Guinea on the basis of surveys of 1679 farms located in 79 villages of the four natural regions of the country. The descriptors used were the number of known varieties, the number of cultivated varieties and Shannon's diversity and evenness index. On the basis of their use rates, varieties were classified as major or minor types at the village scale and as regionally and/or nationally eminent varieties at these scales. Varietal diversity was high, especially in forest Guinea and lower Guinea. Diversity pattern was typical of the subsistence farming system. The high share of local variety reflected the predominance of low management and low input cropping systems. The presence of improved varieties confirms farmers' openness to innovation and to the government policy of promoting improved varieties. Regional diversity reflected the agro-ecological diversity and specificities of each region, the history and the extent of rice-growing systems, and the importance of rice in the local diet. Recent dissemination of NERICA varieties has not caused any reduction of pre-existing varieties. The short-duration NERICA are mainly used as a complement to the long-duration traditional varieties and thus enhance varietal diversity. Risks of diversity erosion seem limited in the current setting of farming system and diversity structure. However, at the village level, the diversity pattern is fragile as the proportion of farmers who used each variety of the village is low and heterogeneous. A continuous monitoring of the dynamics of rice varietal diversity in Guinea is needed.

Keywords: diversity index; Guinea; *in situ* diversity; NERICA; rice

Introduction

Guinea has a very long traditional history of rice growing. Eustache de la Fosse, in his 1479–1480 travelogue *Voyage à la côte occidentale d'Afrique*, mentioned that rice was being cultivated on a large scale in Guinea – this was long before the Portuguese introduced Asian *Oryza sativa* rice varieties to the country. In 1885, Steude described the African cultivated rice species *Oryza glaberrima* from a sample collected in Guinea (Godon, 1991). Currently, rice is cultivated on an area of 600,000 ha, representing more than 40% of the total cultivated area of Guinea. The *per capita* rice consumption level of 90 kg/year is one of the highest in Africa. National demand for rice is rapidly increasing, but improvements in productivity are sluggish. The rise in national production is due mainly to the expansion of the rice-growing area rather than to any increase in crop yield (ORIZA-Guinée, 2005).

Rice is grown throughout Guinea (Fig. 1). Slash-and-burn cropping of upland rice is the most widespread practice, accounting for 65% of the rice-growing area. It is used in all regions, but particularly in forest Guinea (FG) and middle Guinea (MG), in a broad range of morpho-pedological units, rainfall regimes and soil fertility levels. Lowland rice cultivation in freshwater

* Corresponding author. E-mail: ahmadi@cirad.fr

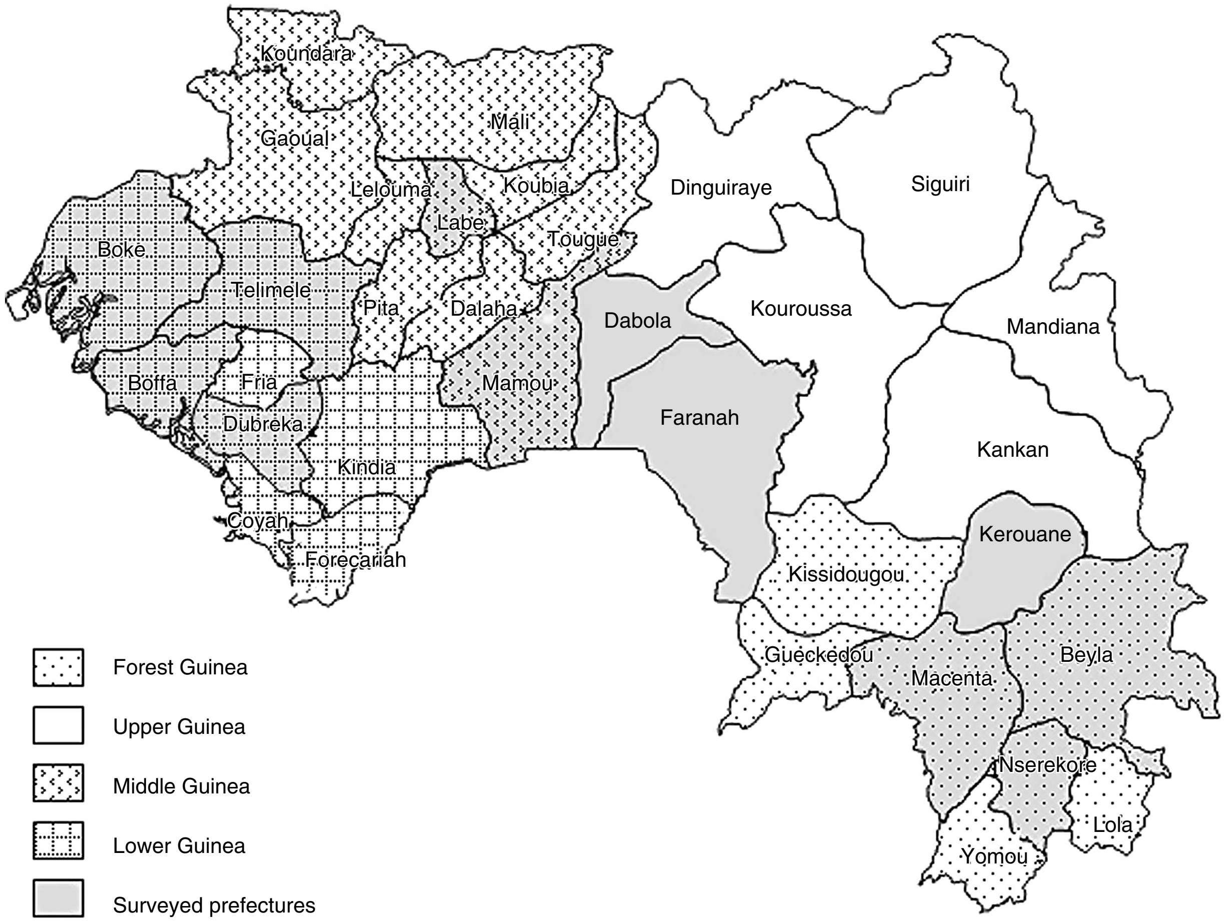

Fig. 1. Distribution of the 16 prefectures where villages and farm were surveyed in the four natural regions of Guinea.

(fluviomarine plains, inland floodplains and lowlands) under highly varied soil water conditions (shallow to deep water and even floating rice, groundwater rice, irrigated rice with various degrees of irrigation control) is important in upper Guinea (UG) and Maritime or lower Guinea (LG). The ‘mangrove’ rice cultivation, with many variants depending on the extent of salinity control measures, represents 16% of the total rice-growing area and is limited to LG (Boun *et al.*, 2001). This high diversity in rice-growing ecosystems makes Guinea an important reservoir of rice genetic diversity in West Africa (Ghesquière and Second, 1983). The country is a centre of diversification of the cultivated species *O. glaberrima* (Portèrs, 1950) and has been proposed for *in situ* conservation of African rice varieties (Bezançon, 1995).

For several decades, improved rice varieties have been disseminated (Dalton and Guei, 2003), and the Institut National de Recherche Agronomique de la Guinée (IRAG) has selected and disseminated high-yielding varieties suitable for each type of rice cultivation system and each natural region of the country. In 1996, IRAG, in collaboration with the Service National de la Promotion Rurale et de la Vulgarisation (SNPRV) and the West African Rice Development Association (WARDA), began a large-scale participative assessment and dissemination of new upland rice varieties created by WARDA. These varieties, derived from interspecific *O. sativa* × *O. glaberrima* crosses, are known by the generic name NERICA, i.e. ‘new rice for Africa’ (Jones *et al.*, 1997). The experience of the Green Revolution in Asia showed how the introduction of improved rice varieties can lead to the disappearance of local varieties (Bellon *et al.*, 1997). In Guinea, the impact of the introduction of new improved varieties on the diversity of local rice varieties is thus a serious concern. To assess the situation, we conducted a survey of the varietal diversity of rice used and preserved *in situ* by farmers in the four natural regions of the country.

Apart from the number of varieties cultivated per farm or village, there is very little published information on descriptors of *in situ* diversity of cultivated species. We attempted to fill this gap by adapting the Simpson’s biodiversity indices (Simpson, 1947; Maguran, 1988) used to describe the diversity of species in natural environments.

Here, we present our survey results, propose new parameters and concepts for describing the *in situ* varietal diversity of cultivated species, and analyse the status of rice *in situ* diversity in Guinea in terms of risk of erosion.

Materials and methods

Sampling of villages and farms

In each of the four natural regions of Guinea, the prefectures in which NERICA rice varieties were recently introduced in one or several villages were identified and one or two of these villages (hereafter called NERICA villages) were selected randomly (Fig. 1). For each selected NERICA, two to three neighbouring villages (hereafter called satellite villages) known to trade with the NERICA village were also sampled. The satellite villages represented almost 70% of the total number of surveyed villages. The total number of villages surveyed in each region was about 5% of the total number in the region. In each selected village, about 10% of the total number of village farms was sampled randomly. In all, 1697 farms in 79 villages were assessed (Table 1).

Survey on the knowledge and use of rice varieties

Inventory of known varieties at the village level

In collaboration with a focus group of knowledgeable rice farmers, a list of all rice varieties which had existed in the village was drawn up to constitute the list of known varieties in the village or village's richness of known variety (*Skv*). The farmers were then asked to classify each of the varieties on the list in one of the following categories: local variety (LV), improved variety (IV) and NERICA variety.

Quantification of rice varieties use at the village level

After the *Skv* were drawn up, each surveyed farmer was interviewed in order to determine his or her knowledge of each variety in the *Skv* list and, for each year over the period 1996–2001, those *Skv* varieties that had been cultivated (*Scf*). The survey was carried out in 2002 in FG and LG, and in 2003 in MG and UG. A use frequency matrix was determined for each variety known in the village and for each year of the survey period.

Data analysis

The following indicators of variety use and diversity index were calculated on a village scale for each year of the survey and for each type of variety, LV, IV and NERICA: the number of cultivated varieties or richness of cultivated variety (*Scv*), the mean number of varieties cultivated per farmer (*Scf*), Shannon's diversity index of cultivated varieties of the village (*Hcv*) and the evenness index of cultivated varieties of the village $Ecv = \exp(Hcv)/(Scv)$ (Maguran, 1988). Regional differences were assessed for each indicator, and each type of variety through ANOVA using village scale data.

Identification of major and minor rice varieties in the villages

In each village, each cultivated variety was classified in the 'major variety' category when the number of farms in which it was cultivated in 2001 was over 50% of the farms surveyed in the village, or in the 'minor variety' category when it was below 50%.

Table 1. Sampling information and rice cultivation data in the four regions of Guinea

	Lower Guinea (LG)	Middle Guinea (MG)	Upper Guinea (UG)	Forest Guinea (FG)	Total Guinea
Rice cultivated area (ha)	217,000	45,000	198,000	179,000	639,000
Rice area % of total cultivated area	54	16	47	87	–
Upland rice area (%)	31	65	60	89	376,800
Lowland rice area (%)	16	34	40	11	147,200
Mangrove rice area (%)	53	0	0	0	115,000
Total number of prefectures	10	8	9	6	33
Number of NERICA prefectures	4	4	3	4	15
Number of prefectures surveyed	4	2	3	3	12
Number of villages surveyed	32	12	18	17	79
Number of NERICA villages	10	4	6	6	26
Number of satellite villages	22	8	12	11	53
Number of farms surveyed	726	240	361	370	1697
Richness of known varieties (*Skr*)	292	52	105	285	669
Richness of cultivated varieties (*Scr*)	153	36	74	165	387
Scr/*Skr*	0.52	0.69	0.70	0.58	0.58

National and regional inventory of the number of distinct rice varieties

The per-village lists of richness of known and cultivated varieties, *Skv* and *Scv,* were pooled to obtain regional lists of the number of known varieties (*Skr*) and the number of cultivated varieties (*Scr*). Finally, the regional lists were pooled to obtain a national list.

Results

Varietal diversity at village levels

Varietal richness

The richness of known varieties at the village level (*Skv*) varied significantly ($P > 0.001$) according to regions, despite significant intra-region variability (Table 2 and Supplementary Table S1). FG was by far the top region, with a mean *Skv* of 33 and a maximum *Skv* of 67, while MG had the lowest *Skv*. The number of known LV and IV was proportional to the total *Skv*. In all regions and villages, LV accounted for a major share of the *Skv*, i.e. 72–88%, while NERICA varieties represented around 10% of the known varieties, except in LG where they only represented 2% of the *Skv*. The differences between regions for *Skv* paralleled differences noted in the extent and history of rice growing in the regions.

The variation in the number of cultivated varieties per village (*Scv*) resembled the *Skv* patterns, but the differences, although highly significant ($P > 0.001$), were not as great between regions (Table 2). Here again, FG was by far the top region, with a mean of more than 20 *Scv* (maximum 37) per village in 2001, while in MG, the mean *Scv* was only 7.9 for the same year. In all regions, LV accounted for 80–85% of the *Scv*, except in the UG region, where they only represented 68%. NERICA varieties represented about 10% of the cultivated varieties except in LG (only 3%). Shannon's diversity index *H* calculated at the village level (Table 3 and Table S2) confirmed the *Scv* variation pattern. Inter-region differences are highly significant. The highest *Hcv* values were observed in FG and the lowest MG and UG. Intra-regional variations in *Hcv* index remained important. Since sample size or richness has an influence on the value of the diversity index, it was not possible to compare *Hcv* value for different categories of varieties.

The average *Scv*/*Skv* ratios calculated at the village level varied markedly between regions: 47% in LG and 70% in MG for all the varieties, and 46% (LG) to 67% (MG) for LV. The ratios were higher for modern varieties, ranging from 62% in LG to 80% in UG. Inter-regional variability in the *Scv*/*Skv* ratio was especially high: 56, 60, 87 and 100% in FG, LG, UG and MG, respectively.

Table 2. Number of known and cultivated varieties per village in 2001 in the four regions of Guinea

	Number of known varieties			Number of cultivated varieties		
Type of variety	Mean	Mini	Maxi	Mean	Mini	Maxi
Lower Guinea (32 villages)						
All	24.59b	10	63	11.88b	4	36
LV	21.72b	7	58	10.00b	2	35
IV	2.87a	0	9	1.80b	0	5
NERICA	0.56b	0	4	0.30a	0	2
Middle Guinea (12 villages)						
All	10.5d	6	16	7.91c	4	11
LV	8.67c	4	14	5.80d	1	10
IV	2.01a	0	4	1.60b	0	2
NERICA	0.75b	0	2	0.80a	0	2
Upper Guinea (18 villages)						
All	16.39c	8	33	11.88b	7	21
LV	11.89c	2	28	7.60c	2	15
IV	4.50a	1	6	3.60a	1	5
NERICA	1.33b	0	2	1.20a	0	2
Forest Guinea (17 villages)						
All	33.06a	9	67	20.76a	6	37
LV	27.06a	8	61	15.90a	6	35
IV	5.01a	0	17	3.20a	0	3
NERICA	3.12a	0	8	1.80a	0	5

LV, local varieties; IV, improved varieties; IV include NERICA. For a given category of variety, mean values of known varieties or cultivated varieties followed with the same letter (a, b, c or d) are not significantly different.

Table 3. Use rate of varieties and diversity index in 2001 calculated at the village level for the four regions of Guinea

	Type of variety	*Scv*	*Scf*	*Hcv*	*Ecv*	*Scf/Scv*
Lower Guinea	**All**	**11.88b**	**2.44b**	**1.94b**	**0.69b**	**0.21**
	LV	10.00b	2.05b	2.01a	0.65b	0.21
	IV	1.80b	0.43a	0.60a	0.40a	0.24
	NERICA	0.30a	0.06a	0.35b	0.45a	0.20
Middle Guinea	**All**	**7.91c**	**1.65c**	**1.79c**	**0.79a**	**0.21**
	LV	5.80c	1.06c	1.35c	0.75a	0.14
	IV	1.60b	0.62a	0.52a	0.72b	0.39
	NERICA	0.80a	0.22a	0.41b	0.65a	0.28
Upper Guinea	**All**	**11.88b**	**2.98b**	**2.19b**	**0.81a**	**0.25**
	LV	7.60c	2.13b	1.75c	0.83a	0.28
	IV	3.60a	0.66a	0.82a	0.76a	0.18
	NERICA	1.20a	0.42a	0.65a	0.61a	0.35
Forest Guinea	**All**	**20.76a**	**4.44a**	**2.57a**	**0.69b**	**0.21**
	LV	15.90a	3.48a	2.21a	0.65b	0.22
	IV	3.20a	0.20a	0.75a	0.34b	0.06
	NERICA	1.80a	0.28a	0.63a	0.41b	0.16

LV, local varieties; IV, improved varieties; IV include NERICA; *Scv*, number of cultivated varieties per village; *Scf*, number of cultivated varieties per farm; *Hcv*, Shannon's diversity index of cultivated variety per village; *Ecv*, Shannon's index of evenness of cultivated variety per village. For a given parameter, mean value of variety of the same categories followed with the some letter (a, b or c) are not significantly different ($P > 0.001$).

Recent evolution of varietal richness at the village level

The *Scv* increased in all regions during 1996–2001 (Table 3) ranging from 25 to 33% according to region. Both LV and IV were affected, but the latter to a much greater extent (40–80%) as compared to LV (around 10–30%). The relative increase in IV seemed to be much less marked in the two main rice-growing regions, i.e. FG and LG.

NERICA cultivation, which was nil in 1996, rose sharply over the 1996–2001 period, but the patterns varied between regions. In 2001, these varieties accounted for 19% of IV in LG to more than 55% in FG. The number of non-NERICA IV also increased from 10% in FG to 50% in UG. The NERICA contribution to the IV *Scv* increase thus varied considerably between regions: 40% in LG and UG, 60% in MG and 80% in FG.

Varietal use and evenness of varietal diversity

The number of varieties cultivated by each farmer (*Scf*) varied significant ($P > 0.001$) according to region (Table 3). The mean *Scf* for FG villages was 4.44, with a maximum of 100, whereas the mean *Scf* were about 2.50 in LG and UG and only 1.65 in MG. There also was a relatively high intra-regional variability in *Scf*. In some UG villages, not all farms cultivated rice and, thus, the *Scf* was less than one.

The *Scf/Scv* ratios were small, 20–34%, and varied little between regions when all the varieties were taken into account. Regional differences in the *Scf/Skv* ratio were greater for IV (6–39%) and NERICA (16–36%). In a given region, the *Scf/Skv* ratio was not the same for the different rice variety categories (LV, IV and NERICA), but no general trend was noted, and it was never over 40% for any category or in any region.

The evenness index (*Ecv*) calculated at the village level (Table 3) is generally much less than one, indicating a high variability in the number of farmers cultivating each of the varieties cultivated in the villages. The inter-regional differences of *Ecv* are significant ($P > 0.05$); the highest values are observed in MG and UG regions. In these regions, the relatively low varietal richness *Scv* was compensated by a higher use rate of each variety. This could reflect that in these regions the cultivation conditions were not as diversified, or that there was a lower level of technical know-how or requirements with respect to rice varieties. The very low minimum values of *Ecv* index in each region highlighted the presence in each region of villages where no IV was cultivated.

Substantial differences in *Ecv* index according to the varietal categories exist. The higher *Ecv* index obtained in MG and UG for improved varieties suggests that there were a small number of IV in each village but each IV was cultivated in a greater proportion of farms.

There were considerable differences between and within regions in the number of major varieties per village (Table S3). FG was by far ahead, with a mean of 2.7 major varieties per village and a maximum of 10 major varieties, whereas the number of major varieties was only 0.75 in MG. Major varieties represented, on average, 10–15% of the varieties cultivated in each village. However, some villages in all regions had no major varieties. Most of the major varieties came under the LV category. Depending on the regions, IV accounted for only 10–30% of the major varieties in the villages, while NERICA represented only 5% of the major varieties, except in MG, where they represented 30%.

Varietal diversity at regional and national levels

Varietal richness at the region level

The total number of known distinct varieties (*Skr*) and of cultivated distinct varieties (*Scr*), identified in the sample of 1697 farms surveyed in the four regions, were 669 and 387, respectively. The absolute values of varietal wealth, in terms of both *Skr* and *Scr,* were much higher in the FG and LG regions when compared with the two other regions (Table 1). But when the number of surveyed farms is also considered, the difference of LG decreased for *Scr*. The *Scr*/*Skr* ratio was 58% on a national scale, and varied markedly between regions, i.e. from 52% in LG to 70% in UG.

Regionally and nationally eminent rice varieties

The lists of the 20 rice varieties cultivated by the highest number of surveyed farms in each region and at the national scale are presented in Table 4 and Table S4. In LG, no variety was cultivated in more than 50% of the villages, while this was the case for at least three to four varieties in the other regions. In FG and UG, regionally eminent rice varieties were found to be cultivated in 75% of the villages. Almost all of the 20 most-cultivated varieties of each region were grown in more than 20% of the villages in the region. However, a much lower proportion of farms cultivated the most eminent variety of each region, ranging from 16 to 31% depending on the region. Only six regionally eminent rice varieties were cultivated on more than 10% of the farms in LG, MG and UG, with 12 recorded in GF.

There was no systematic correlation between the regional eminence and the status of 'major variety' on an individual village scale. For instance, in FG, NERICA 91 was present in 76% of the villages but only cultivated on 11% of the farms. Since it was widely disseminated, this was a regionally eminent variety but it was not a major variety on an individual village scale. In the same region, the Samaka variety was present only in 53% of the villages but cultivated in 31% of the farms. The regional notoriety of Samaka was based on the fact that it was a major variety in several villages.

LV accounted for 70–85% of the 20 regionally eminent varieties, as also observed at the village level. NERICA varieties, on the other hand, only represented 5% of the varieties in LG, MG and UG, and 10% in FG.

There were a very low number of nationally eminent varieties. Only eight varieties were present in more than one region, and only three of them were present in all four regions and cultivated on more than 10% of the surveyed farms. The five leading nationally eminent varieties were also those cultivated in the greatest number of villages and farms.

Of the 20, five varieties cultivated on the highest number of farms nationally were improved varieties, while two were NERICA, with NERICA 28 ranking second nationally eminent variety. Most of the LV on this list had, at some time in the past, undergone mass selection in research stations and had been disseminated by the extension services.

Table 4. List of the 20 most eminent rice varieties at the national level

Varieties	% SV	% SF	% SR	Region
Kaoulaka	33	12	100	All
NERICA 28	35	11	100	All
Samaka	19	9	100	All
Chinois	15	6	75	HG,MG,GF
Djou Kèmè	25	9	50	HG, GF
Moromi	11	7	50	LG, MG
Bloki	8	6	50	HG, FG
NERICA 91	25	4	50	FG, MG
CK 73	18	4	50	LG, HG
Fodeyama	8	3	50	LG, HG
Rok 5	13	7	25	LG
Nankin	16	6	25	HG
Wonkifong	8	6	25	LG
Makeni	11	5	25	LG
Karia	10	5	25	LG
Kouloukwele	8	5	25	FG
Sambankonko	9	4	25	LG
Dalofode	13	4	25	LG
Toyan	5	4	25	LG
Fossa	15	3	25	LG
	79	1697	4	

LG, Lower Guinea; MG, Middle Guinea; UG, Upper Guinea; FG, Forest Guinea. % NSF, % NSV and % NSR, respectively, percentage of surveyed farmers, villages and regions, out of the total, cultivating the variety. Variety name in bold: improved variety.

Discussion

The present survey of varietal diversity, conducted simultaneously on a farm, village, regional and national scale, is one of the first, if not the first, assessment of this kind on cultivated plants in general, and specifically on rice. The names of the varieties, farms and villages were carefully recorded, thus facilitating future time course studies on the evolution of rice varietal diversity in Guinea.

Our village sampling was biased by our initial decision to focus the study in and around villages where new upland rice varieties had recently been disseminated. This choice was based on the hypothesis that these villages only differed from others by the fact that they had been included in the new improved rice variety dissemination operation and that this operation increased the risk of loss of local varieties. For logistical reasons, the prefecture sampling was not evenly balanced between regions, but the total number of surveyed villages and farms was proportional to the relative extent of rice growing in the regions. The results thus provide a baseline estimation of regional diversity.

The basis of our analysis is variety name, but because in traditional cropping systems, a given genotype can be commonly known under different names in different villages, so diversity with respect to names is often an unreliable indicator of prevailing genetic diversity. However, in a parallel study characterizing 170 accessions collected in 14 villages of LG, with 12 molecular markers, Barry (2006) did not identify any accessions of the same genotype under different names, while the majority of accessions having the same name did have the same or rather close genotypes. This good consistency of varietal names confirms the reliability of the name based analysis in the case of rice in Guinea.

Current rice varietal diversity in Guinea

The numbers of cultivated varieties recorded in the farms and villages were comparable to those published previously (Lambert, 1985; Dennis, 1987; Vaughan and Chang, 1992; Lando and Mak, 1994; Kshirsagar *et al.*, 2002; Pham *et al.*, 2002), i.e. several dozens of rice varieties per village and several varieties per farm in different Asian countries. The number of known and cultivated varieties per farm, per village and per region seemed to be closely related to the history and extent of rice growing in the region and to he importance of rice in the local diet. Rice resources were therefore most diversified in LG and FG, where rice is a staple food, as compared to the much lower rice varietal diversity in MG and UG regions where fonio (*Digitaria exilis*), sorghum and millet are the main traditional staple foods. These regional differences reflect actual varietal richness, as the relationship between name based varietal diversity and genetic diversity is good (Barry, 2006), but it may also reflect the fact that in LG and FG, farmers perceive varietal diversity in a more dissected form than in MG and UG.

The *Scf*/*Scv* ratio ranged from 0.06 to 0.4 and the evenness index *Ecv* values were much lower than the maximum of 1.0. This indicated that the proportions of farmers who used each variety of the village were low and heterogeneous. The *Ecv* values were relatively high for improved varieties, specially in UG and MG indicating that, in these regions, the improved varieties were used by a important and homogeneous proportion of farmers.

The major and minor varietal classification confirmed the information derived from the diversity index. Only a small proportion of varieties (10–15% overall) were cultivated by more than 50% of the farmers in each village, while the other varieties were each only cultivated by 5–20% of the farmers.

According to the survey of regionally and nationally eminent varieties, few varieties were present in several villages within a region or in several regions within the country. Even regionally and/or nationally eminent varieties were seldom cultivated by more than 10–15% of the farmers at the scale considered. Moreover, most of these varieties, either LV or IV, had recently been disseminated by the extension services. The situation in Guinea therefore differs substantially from the overall setting in Asia where the Green Revolution has led to the adoption of a small number of IV by a high percentage of farmers, leading to the disappearance of many LV.

The current rice varietal diversity pattern observed at different scales is typical of the subsistence farming system. The farm is clearly the basic decision unit regarding diversity management. The rather important varietal diversity maintained at the individual farm level reflects the multiplicity of constraints (heterogeneities of the cropping environment, constraints of cropping practices, etc.) and/or objectives (harvest for the shortage period, grain quality, etc.) farmers have to face. The high share of LV among the diversity managed by individual farmers reflects the predominance of low management and low input cropping systems. The presence of improved varieties confirms the farmers' openness to innovation and to the government policy of promoting improved varieties, as far as they answer their concerns.

Village varietal diversity is mainly the addition of the diversity managed by individual farmers. The differences between *Scf* and *Scv* as well as the low values of the *E* index reflect the diversity of the rice-growing environments at the village level and the diversity of farmers' cropping strategies. However, the implementation of the individual farmers' strategies and related varietal maintenance decisions rely upon the diversity and varieties exchange mechanisms prevailing at the village level.

Regional diversity reflects the agro-ecological diversity and specificities of each region, as well as the history and the extent of rice-growing systems, and the importance of rice in the local diet. For instance, the high diversity observed in FG is mainly related to the age and the extent of upland rice cropping in a relatively homogenous forest ecosystem, while, in LG, it is related to the diversity of rice-growing ecosystems composed of uplands, fresh water lowlands and mangroves areas. Regional diversity indirectly determines the amount of diversity at the individual village and farm levels, because informal exchanges of varieties among neighbouring villages and farms remain the main way of access to new rice varieties.

Recent changes and future prospect for rice varietal diversity in Guinea

The survey of *Scv* over the 1996–2001 period highlighted an increase in the number of rice varieties cultivated per farm and per village in the four regions. Many phenomena, which may differ for the different varietal categories, could explain this apparent increase. For LV, it is likely that the *Scv* increase was mainly associated with the survey method, which was based on farmers' recollection of practices over several previous years. Farmers more accurately recalled varieties that they had cultivated in 2001 (the year before the survey) than those they grew 7 years earlier. The increase in *Scv* of IV was partially associated with the recollection effect noted above and by the vigorous extension operations undertaken by SNPRV, with the support of IRAG and WARDA. These operations involved a broad range of IV, not solely NERICA varieties, so there was a concomitant increase in the adoption of non-NERICA IV. Contradicting the *Scv* evolution patterns, the *Scv*/*Skv* ratios, which ranged from 0.45 to 0.87, indicated a substantial varietal loss. Actually, the differences observed between *Scv* and *Skv* highlight the dynamic aspect of *in situ* use and conservation of rice varieties in Guinea. Farmers regularly introduce and test new varieties, and then they keep or reject them, which means that they are familiar with many more varieties than they actually cultivate.

Several new upland rice IV, especially NERICA 28 and NERICA 91, have become regionally and/or nationally eminent varieties within 6–7 years. These figures underline the efficiency of government policies to influence farmers' decisions, as these varieties were only recently disseminated by the extension services. They also raise concerns about the conservation of pre-existing varieties. Many reassuring answers can be proposed to such concerns. First, over the last years, the extension services have also contributed to the wide dissemination of some LV varieties, bringing them up to the status of regional or nationally eminent varieties. Second, regionally and/or nationally eminent varieties were seldom cultivated by more than 10–15% of farmers at the scale considered. Third, the number of cultivated varieties did not decrease in the farms or in the villages during this period. And fourth, the new IV varieties adopted by farmers – on account of the positive selective value of their features – complement, rather than compete with, the pre-existing varieties. Our initial field observations seem to confirm this complementarity. The short growth cycle of these new varieties makes them especially attractive since early harvests are beneficial during shortage periods. They also give farmers more cropping flexibility and enable them to increase the rice-growing area on their farms, or even to expand into zones where the rainy season is shorter. This is especially the case in MG where, because of their short cycle, new IV have been integrated into potato-based cropping systems, thus substantially increasing the upland rice-growing area. These new IV give farmers an opportunity to broaden the range of rice varieties with different crop cycle lengths on their farms.

Likewise, in the short term, the introduction of IV seems to be an enhancing and not a threatening factor to varietal diversity. However, it is difficult to predict the medium and long-term effects. A detailed survey of rice varieties in two LG villages indicates a 25–45% increase in the number of cultivated varieties per village between 1980 and 2002 (Barry, 2006). It also indicates that LV, especially the major ones, was exposed to genetic contamination. Therefore, the medium and long-term effects of the introduction of new varieties need to be monitored not only in terms of LV replacement but also in terms of their adulteration.

Another trait of the current rice varietal diversity which should be taken into account when considering the prospects of *in situ* conservation is the heterogeneity in the proportion of farmers who cultivate each variety in a village, as expressed by low values of the evenness index and the existence of major and minor varieties. If we assume that the risk of loss of a variety in a given village depends on these proportions, then minor varieties incur high loss risks. This risk would be particularly high in LG and FG, where *Ecv/Hcv* ratios are small compared with those in MG and UG. But, direct interpretation of the *E* index assumes that all the varieties have the same use-value. This hypothesis is seldom confirmed as each variety has a set of specific properties and, thus, a specific use-value. Moreover, analysis of the genetic structure of local varieties in LG, using molecular markers (Barry, 2006) has revealed that some minor varieties include rare alleles or rare allelic combinations which make them particularly valuable in terms of diversity conservation. Thus, the loss risk analysis should take into account not only the proportion of users, but also the intrinsic use-value and the genetic specificity held by the variety.

Rice varietal diversity in Guinea should be analysed in the framework of factors that influence farmers' concerns, as proposed by Bellon (1996). Farmers' decisions that have an impact on crop diversity are motivated by a large number of criteria including preferred agro-morphological traits, cropping systems, plot characteristics, crop population size and varietal origin. In Guinea, rice is cropped mainly by subsistence farmers, who have a large set of concerns: heterogeneity of the cropping environment, availability of labour and capital, different uses of rice in the diet, generation of sub-products, etc. They therefore need to cultivate a range of varieties, each addressing one or more of the above-mentioned concerns. Minor varieties are cultivated in specific niches or for specific uses. New upland IV are included in the set of varieties maintained by farmers because they perform better than the LV in terms of growth duration. But the LV continue to perform better for low management and low input systems or for straw production. Therefore, the IV are included in the farmers' varietal set without discarding the LV.

Access to new IV apart, other factors that influence farmers' decisions of varietal diversity management, and/or regional or national dynamics of rice varietal diversity, have remained unchanged so far in Guinea, or have evolved very slowly. So, overall, the short-term loss risk of rice varieties, either major or minor, is low. However, a more detailed analysis of the varietal diversity dynamics in LG (Barry, 2006) has highlighted that the deterioration of soil fertility in the upland ecosystems is leading farmers to switch from rice to crops that are less sensitive to soil fertility, like peanut. Thus, rice varieties cultivated in these areas have a high risk of loss. Therefore, beyond the effect of the introduction of new varieties, there is a need to continuously monitor the major factors which influence the dynamics of rice diversity in Guinea. We hope IRAG and/or WARDA will have the necessary resources to establish such a monitoring system or, at least, to implement some time course studies.

Acknowledgements

The French Ministry of Foreign Affairs and the Centre de Coopération en Recherche Agronomique pour le Développement provided funding for this research.

References

Barry MB (2006) Diversité génétique des riz cultivés en Guinée maritime: dynamique des variétés traditionnelles et conservation *in situ* des ressources génétiques. PhD thesis, 174 p., ENSAR, Rennes, France.

Bellon MR (1996) The dynamics of crop infraspecific diversity: A conceptual framework at the farmer level. *Economic Botany* 50(1): 26–39.

Bellon MR, Pham JL and Jackson MT (1997) Genetic conservation: a role for rice farmers. In: Maxted N, Ford-Lloyd BV and Hawkes JG (eds) *Plant Conservation: The* in situ *Approach*. London: Chapman and Hall/International Plant Genetic Resources Institute, pp. 263–289.

Bezançon G (1995) Riziculture traditionnelle en Afrique de l'Ouest: valorisation et conservation des ressources génétiques. *Journal d'Agriculture Tropical et de Botanique Appliquees, Revue d'ethnobiologie*: 3–23.

Boun TL, Souaré D, Bah ES and Bayo L (2001) *Analyse diagnostic des systèmes de production de riz en Guinée. Research report*, IRAG, Guinea, p. 184.

Dalton TJ and Guei RG (2003) Productivity gains from rice genetic enhancements in West Africa: Countries and ecologies. *World Development* 31(2): 359–374.

Dennis JV (1987) Farmer management of rice variety diversity in Northern Thailand unpublish Ph. D. dissertation, Cornell University. UMI No. 8725764. University Microfilms International, Ann. Arbor, MI.

Ghesquière A and Second G (1983) Polymorphisme enzymatique et évolution d'*Oryza sativa* en Afrique. In: *Colloque Electrophorèse et taxonomie*. Sociétété Zoologique de France, Paris, France, pp. 83–90.

Godon P (1991) *Histoire du riz en Guinée: les variétés*. Cirad Presse. Montpellier: CIRAD, p. 10.

Jones MP, Dinkuhn M, Aluko GK and Semon M (1997) Interspecific *Orysa sativa* L × *O. glaberrima* Steud. Progenies in upland rice improvement. *Euphytica* 92: 237–246.

Kshirsagar KG, Pandey S and Bellon MR (2002) Farmer perceptions, varietal characteristics and technology adoption – a rainfed rice village in Orissa. *Economic and Political Weekly*, October, pp. 1239–1246.

Lambert DH (1985) *Swamp Rice Farming: The Indigenous Pahabg Malay Agricultural System*. Boulder, London: Westview Press.

Lando RP and Mak S (1994) Combidian farmers decisionmaking in the choice of traditional rainfed lowland rice varieties. *IRRI Research Paper*. Los Banos, Philippines: IRRI, p. 15.

Maguran AE (1988) *Ecological Diversity and Measurment*. Princeton, NJ: Princeton University Press.

Oriza-Guinée (2005) Actualisation de la Lettre de Politique de Développement Agricole LPDA. *Observatoire riz et autres produits vivriers en Guinée* 11: 3–7.

Pham JL, Morin SR, Sebastian LS, Abrigo GA, Calibo MA, Quilloy SM, Hipolito L and Jackson MT (2002) Rice, farmers and genebanks: a case study in the Cagayan valley, Philippines. In: Engels JMM, Brown AHD and Jackson MT (eds) *Managing Plant Genetic Resources*. London: CAB International, pp. 149–159.

Portères R (1950) Vieilles agricultures de l'Afrique tropicale: centre d'origine, de diversification variétale primaire et berceau de l'agriculture antérieure au XVI$^{\text{ème}}$ siècle. *Agronomie tropicale* 44: 165–178.

Simpson EH (1947) Measurement of diversity. *Nature* 163: 688.

Vaughan DA and Chang TT (1992) *In situ* conservation of rice genetic resources. *Economic Botany* 46: 368–383.