Rice Genetic Resources in Postwar Sierra Leone

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This research was conducted under the auspices of the Graduate School Experimental Plant Sciences (EPS).

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Thesis
submitted in partial fulfilment of the requirements for the degree of doctor
at Wageningen University
by the authority of the Rector Magnificus
Prof. dr. M.J. Kropff,
in the presence of the
Thesis Committee appointed by the Doctorate Board
to be defended in public
on Tuesday 15 September 2009
at 11 AM in the Aula

Robert T. M. Chakanda
Rice Genetic Resources in Postwar Sierra Leone,
164 pages.

PhD Thesis, Wageningen University and Research Center, The Netherlands (2009)
With references, with summaries in English, and Dutch

ISBN: 978-90-8585-423-4

Abstract

This research presents the effect of the 10-year long civil war in Sierra Leone on rice genetic resources, using farmers and their seed systems in three selected districts as reference points. The war disrupted all forms of production and development in the country and like other sectors of the economy, agricultural production and the conservation of plant genetic resources at the farm level was severely affected. It emerged that farmers' effectiveness to cultivate and manage their seed systems and the options to grow rice under insecure conditions were disrupted at different levels in the three districts studied. However, the general consequence of the war in all of the districts was that farmers lost considerable amounts of their seed stocks. Total losses for some rice varieties was averted because of the occurrence of a number of varieties in more than one village in the same region, which was a result of farmers seed exchange systems, and also due to farmer movement during the war. The majority of the varieties that were reported lost were actually "dispersed" in the regions, indicating good options for post-war recovery.

There was little evidence that the genetic composition of rice varieties were significantly altered as a consequence of the war, except for the total loss of upland varieties in one of the districts. The varieties that had the highest survival were those that had wider pre-war distribution, showed plasticity in growing habits wherein they demonstrated the potential to grow in both agro-ecosystems and in the different districts, and the fact that they existed in many different forms.

Statistical analysis showed a clear distinction between upland and lowland varieties, which demonstrated the effectiveness of farmer selection with regard to the two production ecosystems. This was different for the periods defined as pre-war and post-war. Pre-war varieties were less well defined in this respect. Further to this, there was evidence of a change in rice genetic resources between the pre-war and post-war situations, which was demonstrated in the number of varieties for each of the two ecosystems. Despite these changes, and the losses in seed stocks as a consequence of the war, genetic diversity increased in post-war rice varieties.

AFLP results indicated that rice varieties in Sierra Leone possess different levels of intra-variety variation, which makes it difficult to identify homogenous genotypes at the seed unit level. This was attributed to genetic exchanges caused by farmers' practices of growing different varieties in mixtures. The variation however does not alter the profile of inter-variety genetic differences, which remains large enough to distinguish one variety from the other. It demonstrates that the genetic composition of rice varieties remains distinct from one another, and that variety names in Sierra Leone are good indicators for genetic diversity of rice at the farm level.

ACKNOWLEDGEMENT

I give God the Glory for the great opportunities He gave me during this research work.

I shall begin with thanking my family, starting with my wife Finda Chakanda and the children Sia, Florence and Roberta who had to miss me for months in a couple of years while I conducted field expeditions in the then potentially dangerous countryside of Sierra Leone. Sometimes it went for weeks without telephone contact, and I understood the difficult situation that they had to endure. Back in the Netherlands, I still had to make this thesis a reality at the expense of letting them go through several days and evenings without my presence.

During the years of my work both in Sierra Leone and The Netherlands many people and institutions have contributed to the successful completion of this study. It will be my wish to mention all those that I would like to acknowledge, but just in case I miss out on some names, do understand that everyone has been as important to me as any other for the successful completion of this work. It is therefore with great pleasure and gratitude that I make the following acknowledgement.

My appreciation goes to the Wageningen University and Research Centre for the "out of the normal" sandwich program, and the initial funding to start the study. With great appreciation I would like to thank in a special manner the Centre for Genetic Resources, the Netherlands (CGN) and most especially the director Bert Visser who almost single-handedly sponsored more than 70% of the entire study program. CGN funding was not only directed at the core research, but also to cover all the extra logistics and staff salary that could not be provided in Sierra Leone. Bert, please accept my thanks particularly also for the job at CGN, which provided me with work environment and unrestricted use of office logistics throughout the program in the Netherlands. My appreciation also goes to the Biosystematics Group who adopted my research, and at some point co-funded the last leg of the field visits together with the CGN. I also do acknowledge with thanks the financial assistance of the Nederlandse Organisatie voor Wetenschappelijk Onderzoek (NWO) that was used to support the second field trials in Sierra Leone.

My sincere gratitude goes to my promotor Prof. Dr. Marc Sosef, Chair of the Biosystematics Group, Wageningen University for his professional guidance and patience throughout the study period. I am deeply indebted to my co-promotor Dr. Ronald van den Berg, who followed every single step with me, not only working on research planning and eventually the thesis, but also getting involved with the difficult questions of finance, travels and almost every bit of everything. Dr. Bert Visser of CGN was the second co-promotor, which has made my indebtedness to him even stronger. Thank you all for supporting me through the difficult times of conducting this study, which was combined with long delays on my side for both work and travels, and the inconvenience that this caused. You shared my interest in Sierra Leone, war and the rice crop, three subjects that were entirely new to you. I am grateful to my external supervisor, Dr. Evert-Jan Bakker at the statistics department Biometrics, Prof. Dr. Fred van Eeuwijk, and his assistant Paul Keizer who took the first look at the statistical component of the field results. Still at the Biometrics, I finally came in contact with Prof. Dr. Cajo ter Braak who made the invaluable contribution to not only analyse the morphological data, but came up with the method to quantify genetic diversity using his software CANOCO.

My special thanks go to my colleagues at CGN, Frank Menting, and Willem van Dooijeweert, with whom I shared office space at the start of this research. I also strongly appreciate the efforts of Rob, Theo and Mark for their invaluable ideas on statistical principles they shared with me, and the reading and commenting on some of the chapters of this thesis. My thanks also go to Elizabeth and Noortje who together contributed to provide a friendly environment at the work place. I cannot forget the former secretary Helga, who really spoke Dutch to me all the time, and later when she left, came Woukje, who made efforts to improve my written Dutch. At the Biosystematics department, I would like to thank Ria for carrying out the AFLP component of the research.

I am especially thankful to my Dutch Christian friends, Wim and Corrie, Max and Sonya, Bendix and Judith, Seerp and Maike and the entire membership of the Church of Salem whose friendship, fellowship and prayers saw me through some of the most difficult moments of my personal life. This gratitude extends to my Christian Dutch family, the Kwikkels who adopted my family in Christ ever since I came to the Netherlands.

In Sierra Leone, I am grateful to Dr. Dennis Taylor for supervising my research work during the expeditions and the field trials. The survey team: Franklyn Kamara, Godwin Torto, Kabba Nabay (deceased), Sahr Lebbie, Kadiatu Jawara, Grace Monde, Kadiatu Turay, Mohamed Mattia, Simplicity and Confey provided remarkable assistance and demonstrated bravery and professional conduct during the whole period of the expeditions. Thank you all for the long hours spent in the field and the long drives sometimes at night. Thanks to the interpreters and those who served as forerunners and were hired on a daily basis to assist during the survey. I am also indebted to my respondents, especially those who served as key informants, amongst whom are Mr. A. B. Conteh of the Rice Research Station and Sahr Lebbie of Maduya village. I am sincerely grateful to my field assistants: Mr. Edward Munu, Hassan Kamara and Sylvester Rogers who conducted the field trials for two years. The agricultural officials in Conakry, Republic of guinea and the zone frontier authorities at the border checkpoints on the Guinean side deserve my appreciation and to them I am very thankful for allowing me to conduct collecting missions in their country.

This thesis is dedicated to the brave men and women farmers in Sierra Leone, some of whom paid the ultimate war price, and those that survived are doing all they can to save rice genetic diversity for present and future generations.

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Chapter 1

Introduction

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1.1 Justification

Sierra Leone is in the process of recovering from the war that affected every fabric of its society in recent history. The conflict took an almost complete toll on agriculture and food production and is known to have destroyed all supporting infrastructure including roads, storage facilities and seed processing plants that were used to maintain on-farm genetic resources. Furthermore, both direct and indirect impacts on rural communities resulted in the deterioration of the principal components of agricultural biodiversity: the people, the ecosystem and the on-farm genetic resources.

The civil war that started in 1991 lasted for nearly 11 years. A rebellious group known as the Revolutionary United Front sought to uproot all forms of central governance, which led to one of the most complex wars of the last century (Peters and Richards, 1998; Smith *et al.*, 2004). Destruction started in the Southern and Eastern parts of the country in 1991 and spread to the rest of the country by the end of 1994, becoming most devastating in 1995. It caused large-scale displacement of farmers, thereby cutting off large portions of land from production. Apart from being displaced, many farmers, particularly those in areas that were under frequent attacks also lost their seeds, tools, on-farm storage facilities and other productive assets to the extent that even those returning from the displacement camps have not been able to resume normal production. Other consequences included serious damage to agricultural lands as a result of unregulated mining, activities, illegal lumbering and military exercises (Garnett and Utas, 2002; Lebbie, 1998). National reports estimated that about 180000 farming families were directly affected by the conflict. This was caused by frequent insurgencies in regions with farming populations in the interior of the country, which resulted in vicious havocs to the rural communities. Destruction of property was extensive, and farmlands were invaded by fighters in search of food and loot, leading to a total collapse of crop production and biodiversity management at the farm level.

In order to arrive at the main objective of this research, the impact of the civil war on farmers' genetic resources has to be understood and the present study aims at such understanding. In this introductory chapter the necessary background information on Sierra Leone is given, which will be followed by the problem definition leading to the research questions and finally the outline and setup of the thesis.

1.2 Background

1.2.1 Natural features

Sierra Leone is a classic agricultural country whose national employment sector depends largely on food and cash crop production. The country is located on the west coast of Africa, north of the equator, with a land area of 27,699 square miles (71,740 square kilometers), bounded by Guinea to the north and northeast, Liberia to the south and southeast, and the Atlantic Ocean to the west (Figure 1.1). Starting from the Ocean, the topography begins with a low-lying coastal ecosystem encompassing approximately 250 miles (400 kilometers) of sandy coastline. At river distributaries, mangrove swamps merge with forested coastal plains. Farmland and a much higher interior plateau landscape occasionally transect this ecosystem. The plateaus rise to elevations of about 450 m above sea level for much of the inland country and are characterized by vast stretches of seasonally inundated valley swamps (IVS). To the north and northeast, the plateau gradually gives way to more hilly landscapes, such as the Tingi Hills that harbour numerous inland swamps. The hills eventually merge with mountain ranges of the northeast, e.g. the Loma mountains reaching peaks of over 1,800 m altitude (COI, 1995; Odell *et al.*, 1974).

Figure 1.1: Map of Sierra Leone showing position in West Africa

1.2.2 Ethnic composition

The mainland of Sierra Leone is home to many ethnic groups, including sub-ethnic minorities, which account for the farming populations of the rural regions. There are between 15 and 20 recognized ethnic groups in different regions of the country, including the numerous Mendes (in the south and south-eastern regions) and Temnes (in the north and north-western plateaus). Other major tribes include the Limbas, Fulanis, Madingos and Korankos that occupy the far northern axis; Kono and Kissi in the Eastern plateaus, and the Vai to the extreme south-west (McCulloch, 1951). Each of these groups has very strong and distinct traditional values that are often reflected in their social systems and agricultural practices (Tilburg, 2001). These practices have a strong relationship with the landscape type, and the ethnic groups practice very noticeable traditional differences in crop husbandry that characterizes most of their land use systems.

1.2.3 Biodiversity aspects

Until the 1900s, Sierra Leone was endowed with a vast land cover of virgin forest that for decades remained untouched and supported wildlife and biodiversity (Cole, 1968). This evergreen and semi deciduous forest belt stretched from Liberia, cutting across Sierra Leone and into Guinea, and was formerly known as the Upper Guinea Rain Forest, or alternatively as the Guinea Lowland Forest (Gwynne-Jones *et al.*, 1977). Forests are still the habitats of most of the fauna and flora in the country. Over the last two decades, however, there has been a seemingly unchecked loss of the natural forest cover in the entire sub-region, which has led to major ecological concerns. As the forests dwindle, so do the populations of living organisms, raising fears about the loss of vital biological diversity (Myers, 1975; Teleki, 1980).

Several factors have accounted for this large-scale deforestation. These include slash-and-burn farming practices, road construction, fuel wood collection, mining, shelter construction, logging, charcoal burning, and bush fires. In the late 1970s, the FAO supported a Land Resources Survey Project to assess land cover patterns, covering the entire country. The final report suggested that the primary rain forest had shrunk considerably, with minimal forest re-growth and secondary forest formation (UNDP/FAO, 1980). For much of the deforested areas, savanna and a savanna mosaic type of vegetation has now replaced the primary forest cover.

The conservation of biodiversity in Sierra Leone has long been dealt with as synonymous to the conservation and management of forest and wildlife genetic resources. Almost every reference to conservation mentioned in research, education and government circles deals with the rain forest and wildlife, exclusively leading to conservation efforts protecting forest resources. In particular, the international donor community places major emphasis on the protection of forest resources and the life forms within. The Biodiversity Support Program (BSP), a consortium of the World Wildlife Fund, the Nature Conservancy, and the World Resources Institute, which obtains its financial support from the United States Agency for International Development (USAID), recently supported forest survey and regeneration programs in the country (Squire, 2001).

However, utilization patterns of traditional agricultural systems and forest systems are inseparable in Sierra Leone due to the intertwined nature of natural and agricultural biological diversity. The main agricultural practice for food production to date is the rice-based system, which involves age-old traditional practices that are conducted within two major agro-ecosystems, namely the upland and lowland ecosystems. The upland ecosystem, which by far is the largest involves shifting cultivation, which is closely linked to the resources and biological systems provided by the forest. Farming in the uplands involve slash-and-burn practices, by which forest cover is removed and plant remains are burnt to clear the land for cultivation (Kanmegne, 2004). Increasing rice production in this ecosystem using forest land has therefore drastically reduced the area of primary forests in Sierra Leone over a 30-year period (Davies, 1987). The practice has further led to the depletion of soils due to soil erosion, which in turn reduces the production potential of the agricultural ecosystem itself over time.

1.3 Agro-biodiversity concerns

Rice is the main staple crop in Sierra Leone, and given the current situation of overall plant genetic resources nationwide, there is a growing concern within the research community about the state of the biological diversity of the rice crop and of the other crops that are grown within the rice-based farming systems (IAR, 2005). The diversity of farmer-managed rice varieties at all levels is being threatened due to the factors mentioned above, such as deforestation, which are acting in combination with the negative effects of shifting cultivation and the loss of habitat (Sperling and Loevinsohn, 1993). In addition to these factors, the occurrence of the civil war has drastically increased concerns about the level of on-farm managed rice genetic resources in the entire country (Longley, 1997). No one knows for sure to what extent rice genetic resources have been affected by the factors that threaten general biological diversity, and what the effect of the war has been to this effect.

1.4 Problem definition and purpose of the research

Given the number of factors mentioned above that have the potential to affect the genetic resource base of the rice crop, this research is concerned with the effect, if any, that the war has had on its diversity and the production system that supports it. There is mounting evidence about the destructive effects of the war on civil society, the agricultural community and the natural ecology (Peters, 2006; Squire, 2001), but what this means for the genetic diversity of the rice crop remains to be investigated. As a first step towards this, there is the need to determine the consequences of war for the major components that sustain the conservation and management of rice genetic resources in the country, namely, the farming community, the ecosystems and the on-farm genetic resources itself. It will involve an analysis of the disturbances that occurred within the farming communities, the production systems and finally the need to assess the state of the existing plant genetic resources that survived the war. Only then can we decide on the best strategy for the reconstruction of farming communities, ecosystem rehabilitation and seed restocking.

One complicating factor, however, is that there has been very little technical research directed towards understanding the details of rice biodiversity in the country before the war. Seventy years of research efforts on farming systems and the rice crop at the Rice Research Station, Rokupr has not addressed the issue of the crop's diversity in farmers' fields and the threats these resources have been facing. The events of the war in Sierra Leone, be it regretful, now offer an added motive for studying the state of the country's on-farm plant genetic resources for rice in the immediate aftermath of war. They also offer a chance to evaluate the effects of the country's civil war and farmer displacement on on-farm genetic resources management and the general state of farmers' seed systems.

A number of agencies are willing to offer seed relief to farmer communities, but they often lack information about farmers' social contexts, and have even less information on their seed systems and the type of help that the farmers require most. In agricultural terms, the strategy to redress normal systems after conflicts using seed materials needs to be based on data regarding genetic resources gathered at the farm level. This is vital to most stakeholders, including seed sector organizations that may need to get back into operations, e.g. the German support Seed Multiplication Projects (SMP) and the International Agricultural Development Projects that were operational before the war.

The present research is therefore intended to investigate on-farm biodiversity for rice in terms of the genetic resources present immediately after the war in Sierra Leone, the reasons behind the current state of affairs of the farmer community, and the possible options for restoration of rice bio-diversity management systems. The outcome is expected to identify protocols for germplasm recovery and necessary areas of further research aimed at enhancing farmers' existing ability to manage their own crop genetic resources. The results could help to set priorities for interventions with a lasting impact on both the local population and the agricultural system.

For this research, rice agro-biodiversity is considered within the context of the full diversity of the rice crop and its varieties that exist in the traditional farming systems. The objective of the present research therefore is to investigate on-farm genetic diversity of the subsistence crop rice in post-war Sierra Leone, and to uncover the impact of the civil war on this genetic resource and its related farming systems.

1.5 Research questions

Although this research focuses on the nature of rice genetic resources in post-war Sierra Leone, a broad-based approach was adopted in order to obtain a better understanding of the overall situation. This included approaches that are defined by questions surrounding the historic background of rice diversity in the country, the different farming systems for rice, the general overview of rice genetic resources before, during and after the war, and a number of other factors. In order to arrive at specific answers to these broad areas of interest, the following general and specific research questions were outlined as a way of guiding the research to the desired conclusion:

1. How did the farming systems, seed systems and institutional influences define the genetic resources base for rice before the war in Sierra Leone? How did these systems respond to the stresses of the 10-year long war in the country?

2. What are the major challenges that could affect field expeditions in circumstances of acute insecurity caused by war? What security and social methods could be appropriate for collecting valuable data in such post-war situations?

3. How did the war affect the different farming communities in the selected districts? If differences were experienced, how did this affect the seed systems of the farmers?

4. What is the direct effect of the war on rice genetic resources in Sierra Leone?

5. What was the effect of the war on specific rice varieties and how did this define the state of rice genetic resources in post-war Sierra Leone? Which specific plant characteristics determined the survival of the varieties through the war period?

6. To what extent can phenotypic characterization distinguish between post-war rice varieties in Sierra Leone? By which of the two perspectives, district and ecosystem, could the rice genetic resources be best defined, and what the were implications for seed rehabilitation?

7. How does intra- and inter-variety variation determine the genetic relationship between and within farmers' varieties? What is the genetic relationship between synonymous varieties grown in different regions in the country?

1.6 Outline and setup of the thesis

Chapter 1 presents a general introduction of the research, which leads to the definition of the problem. The civil war is mentioned as the background of events that has raised concerns over the genetic diversity of rice in Sierra Leone, and which eventually leads to the research questions.

Chapter 2 outlines the background of the rice farming systems in Sierra Leone and how these relate to the management of genetic resources of this crop. The major institutions that contributed to the state of affairs of farmers' rice genetic resources management and enhancement of this crop are presented.

Chapter 3 outlines the methods that were employed during the expeditions for rice germplasm collection from farmers. Details are presented about the approaches, starting with the preparations, criteria used for selecting study regions, rice sample collecting, and interview methods for obtaining the farmers' versions of events.

Chapter 4 discusses the nature by which the war affected the farming communities in each of the study regions and how this in turn affected their rice genetic resources. An inventory of rice varieties lost and recovered is presented.

Chapter 5 builds upon chapter 4 to describe in detail the specifics of the varieties with direct reference to variety names, ecosystem of cultivation and the properties that enabled them to survive the war.

Chapter 6 phenotypically characterizes the rice varieties in order to describe the genetic diversity that is present within the study regions. Attempts are made to explain the diversity within the rice genetic resources and how they fit into the two main agricultural systems.

Chapter 7 compares the rice genetic resources that existed 30 years before the current study (regarded as pre-war collections) and those collected for this study (post-war) in order to determine the effect of the civil war on the diversity of rice varieties.

Chapter 8 analyses the varieties using AFLP technology in order to determine relationships within and among varieties in three ways: 1) the level of intra-variety variation, 2) inter-variety variation and consistency in variety names, and 3) similarities or differences between varieties with the same names but occurring in different countries.

Finally, chapter 9 summarizes the main significance of the research that led to the overall conclusions, and discusses the implications of the findings on the genetic resources situation for rice in Sierra Leone. Additionally, the chapter ends with a number of recommendations for future research.

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Chapter 2

Rice production practices in Sierra Leone

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2.1 Background

The economy of Sierra Leone and livelihoods of its inhabitants are to a large extent dependent on agriculture, accounting for over 40% of the income of much of the population, and 50% of the Gross Domestic Product (Jalloh *et al.*, 2000). The agricultural sector is relatively underdeveloped and is dominated by rice farming, which provides employment to rural communities. Rice farmers live on small, scattered farms, following a scheme of bush-fallow rotation, slash-and-burn field preparation, and limited use of fertilizers. Agricultural exports are limited to a number of cash crops, i.e. coffee, cocoa, palm kernels, and ginger (IADP, 1982).

2.1.1 Rice-based production system
Rice is regarded as the staple and main source of calories in the whole of Sierra Leone, which makes it very well established in the agriculture and diets of the 5 million inhabitants. The country lies within the rice belt of West Africa where *Oryza glaberrima* Steud., known as African or red rice, was domesticated and developed. In addition to *O. glaberrima*, much of the rice grown today belongs to *Oryza sativa* L. or Asian rice. Rice fields cover 400,000 ha and annual production is estimated at 630,000 tons (FAO, 2004). In addition to rice, other main food crops grown for subsistence on the same farm and often in the same field are sorghum, millets, maize, cassava, yams, tomatoes, and pepper (Yillah, 1993). For each of these crops, genetic diversity management and conservation is the key factor for sustainable production and food security.

Genetic diversity in rice is therefore vital to traditional farmers who are known to grow large numbers of different varieties in order to achieve sustainable harvests (Richards, 1985). Landraces are still widely cultivated and farmers literally manage their rice genetic resources through landscape management strategies and variety selection practices. Kandeh and Richards (1996) state that the effectiveness of farmer management practices of rice in Sierra Leone is demonstrated in the conservation of landraces that otherwise might have disappeared.

2.1.2 Seed system
The success of production, management and conservation of rice genetic resources in Sierra Leone, like many subsistence production systems around the world lies in the effectiveness of the traditional seed systems through which farmers conduct selection, production and diffusion of their seeds. The system is also referred to as an informal seed system, which operates at the community level through a number of social mechanisms and corresponds with what is generally known as the traditional seed sector (Cromwell, 1990). The reliability of this sector depends on different components through which farmers obtain seed for planting, including farmers' own store, the market, gifts from family and friends, and a number of seed exchange mechanisms (Agrawal and Worede, 1996). According to Almekinders *et al*. (1994), traditional seed systems are non-specialized seed control mechanisms that are integrated into the production of grains, roots and tubers for consumption and marketing.

2.1.3 Marginal environments and agro-biodiversity
Many of the agricultural lands of Sierra Leone lie in marginal environments, which are often characterized by soils that have been heavily depleted of nutrients. In continuously dealing with variable ecosystems, the Sierra Leone farmer in the rice-based farming systems uses crop diversity to farm in complex and heterogeneous environments. This crop diversity has allowed production sustainability in situations characterized by distinct topographic settings,

soil qualities, and rainfall regimes (Richards, 1986). It is widely acknowledged that different crop mixtures, both intra- and infra-specific, in marginal production systems as in Sierra Leone serve to minimize the risks of crop failure, and provide a sustainable means for on-farm conservation genetic resource conservation (Zhu *et al.*, 2000; Zhu *et al.*, 2003). Furthermore, in tropical agricultural systems where pests and disease causing pathogens are constantly undergoing genetic changes, on-farm crop diversity provides the only means of sustained defense for resource-poor farmers (Clawson, 1985; Glass and Thurston, 1978).

2.1.4 Farmers' strategies in genetic resource management

Farmers' management of crop diversity in Sierra Leone reflects the importance of conservation practices. Especially within the rice-based system, farmers have successfully developed methods that enable them to manage and conserve multiple varieties of the crops they grow. Through natural and farmer selection the diversity generated both between and within rice varieties exhibits highly adaptive features to the variable agro-ecosystems in the country. Different research groups have adopted participatory methods in order to understand the principles underlying farmers' choices, the roles of the accompanying land use systems and the management of their fields (CBDC, 1996).

2.1.5 NGO interventions in farm-based activities

On-farm practices for biodiversity management in the country are recognized as a multi-layer cultural phenomenon by a number of non-governmental agricultural support organizations. One such organization is the Community Biodiversity Action Network (CBAN), which has been conducting the Community Biodiversity Development and Conservation (CBDC) Programs in the country. Other NGOs, such as CARE, Action Aid and CARITAS, are also working with farmers but not directly involved in biodiversity management. These programs have emphasized aspects of *in-situ* genetic resource conservation, adequate biodiversity management practices and livelihood security strategies for smallholder farmers. One key factor emphasized by CBAN is the need for community involvement and support for achieving genetic resource conservation and for the sustainability of future management options. Based on the importance of agro-biodiversity to the Sierra Leone farmer, the CBDC partners argue that much of the agro-biodiversity could be conserved through collective farmer management practices, and without any trade-off to sustainable crop yield (CBDC, 2006).

As part of its Plant genetic resources (PGR) programs, CBAN addressed the various agricultural land-use systems within the whole concept of *in-situ* conservation and development. A dominant agricultural system for the cultivation of rice is shifting cultivation and this is mostly practiced in the upland ecosystems (see below) (Margery and Alcorn, 1987). It comprises a multi-layered farming practice that is composed of basic traditional features through which farmers maintain high levels of diversity of both rice and non-rice staple crops on their fields. Almost all the crops included within the subsistence production mentioned earlier are included within the mixed-cropping system, which makes it common to find between 10 and 15 types of crops in a single field during one growing season (KIADP, 1997). The practice is common amongst traditional farmers across the globe. Lessons learnt from Thai farmers suggest that any form of disruption to this sort of agricultural system leads to a drastic loss of crop genetic diversity (Sutthi, 1990).

2.2 Agricultural systems in Sierra Leone

In Sierra Leone, the most extensively practiced agricultural system for food crop production is the rice-based farming system, which can be divided into two sub-systems: the upland sub-system and the lowland sub-system, which are described below:

2.2.1 The upland sub-system

Most of the rice farming is conducted in the upland agricultural system, which accounts for 60% of the total national rice areas (AIADP, 1975; FAO, 2004). Earlier estimates put it at 80% of total rice area under cultivation (Kline, 1956; Knickel, 1988), suggesting a decline in the coverage of this ecosystem over the years. Upland soils are characteristically variable and composed of heterogeneous soil particles and chemical content due to differences in parent material (Odell *et al.*, 1974). These soils are often well drained and highly leached, exhibit low fertility, and vary in depth, gravel content and texture. Hill slopes consist mostly of gravelly loams mixed with clay that shows varying levels of sand contents. Cation exchange capacity for most plant nutrients (except for potash) is generally low. Mineral deposits give rise to acidic soils, with pH generally below 6.0, whereas high levels of aluminum result in metal toxicity. In some niches, however, high deposits of organic matter result in higher levels of fertility (McKenzie *et al.*, 1977; Odell *et al.*, 1974).

The upland sub-system supports a wide range of different crop types planted in a mixed cropping pattern with rice in a single growing season (KIADP, 1997). The regular cultivation practice features rice seed that is mixed with seeds of other crops like sorghum, millet and maize before broadcasting the seeds in the field. This enables farmers to maintain a range of genetic diversity of the different crops species at the farm level. Shifting cultivation, that is key to upland farming, involves the continuous relocation of farms across ecosystems in the search for fertile land (TDRI, 1985). Farmers often cultivate a piece of land for a maximum of two years, after which they leave it fallow and move to another location. Shifting cultivation therefore provides for continuously introducing crop varieties to micro-niches that may lead to wide adaptability and further provide the opportunity for an interaction between crops and wild relatives. In the upland sub-system average yields for rice vary between 700 – 900 kg per hectare (Due and Karr, 1973).

2.2.2 The lowland sub-system

The lowland sub-system accounts for the remaining 40% (earlier reports (Kline, 1956; Knickel, 1988) give an account of 20%, indicating an increase in this system) of cultivated land for rice, and comprise four agro-ecosystems: inland valley swamps (25%), mangrove swamps (7%), riverrine grasslands (3%) and bolilands (5%) (AIADP, 1975).

Although the inland valley swamps are highly productive for rice per unit area cultivated, less than 5% is being used in the country so far (FAO, 2004). The main production constraints in this ecosystem are the variable nature of the soils due to poor drainage, iron and other heavy metal toxicities, low pH and the lack of potential to retain nutrients, especially nitrogen (Baggie and Bah, 1993; George *et al.*, 1992). Nearly 39% of the total national rice yields are obtained in inland valley swamps. Mangrove swamps are found in coastal areas, and are subject to daily tidal influences from the sea, which is unlike other lowland systems that are seasonally inundated with rain water (Jones, 1983). Although the tidal influx causes salinity problems, mangrove swamps have more production potential than the rest of the lowland classes (Sampong *et al.*, 1988). Other constraints associated with mangrove soils are high acid sulphate toxicities, which when allowed to dry causes pyrites to oxidize resulting in extreme acid conditions unsuitable for rice cultivation.

The riverrine grasslands are deep-water flood plains that can retain water for long periods, with the potential of holding standing water from 0.5m - 3.0m during the rainy season. Long rooted, floating rice varieties are the only suitable types adapted to this ecosystem. Bolilands are vast saucer-shaped, poorly drained depressions with characteristic clayey hardpan soils that become easily inundated during the rainy season, but also dry out quickly during the dry season. This landform is found in the northern regions of the country lying between major rivers. Each of these agro-ecosystems has characteristic features and associated constraints for which farmers meticulously select their rice varieties.

Rice grown in the lowlands and the tidal wetland ecosystems normally occurs in pure stands, with low or no application of external inputs. Seeds are pre-germinated, directly seeded or established in nurseries, which is followed by transplanting of seedlings to permanent stands. It is estimated that about 90% of the cultivated swamp rice consist of traditional landraces, which respond poorly to fertilizers. The lowland fields, particularly those in the inland valley swamps and the mangrove swamps, serve for vegetable production after the rice has been harvested.

2.3 Agencies associated with rice agro-biodiversity

Evidence of systematic investigation of rice genetic resources in Sierra Leone dates back to the 1920s when research was initiated by the colonial governor (Jusu, 2000). Since this early period agricultural organizations and almost all developmental agencies somehow got involved with rice production. Below are some of the institutions that have direct concerns and impacts on rice genetic diversity in the country:

2.3.1 The Rice Research Station

Established in 1934 at Rokupr in the Kambia district, North-Western Sierra Leone, the Rice Research Station (RRS) acquired the mandate to conduct research on the rice crop, including the development of sustainable practices that support traditional farming systems (Jusu, 2000; Richards, 1986). The first researchers appreciated the wealth of diversity and adaptive potential already present in the local rice varieties. However, they were concerned about the very low yield ability of *O. glaberrima* that was predominant in the region, and this led them to introduce *O. sativa* from other rice-growing regions in the world (Table 2.1). This was done in addition to the introduction of varieties by colonial research visitors (GOSL, 1953).

Table 2.1: Summary of the origins and number of rice varieties introduced into Sierra Leone.
Source: GOSL, 1953

		Number of varieties			
Year	**Country**	**Introduced**	**Retained**	**Discarded**	**Failed**
1928	French Guyana	1	1	0	0
1931 - 1946	Madras	28	4	20	4
1934 - 1951	British Guyana	18	9	9	0
1934 - 1951	Ceylon (Sri Lanka)	62	56	4	2
1936 & 1951	Hong Kong	9	5	1	3
1936	Burma	4	2	2	0
1942	Peru	22	2	19	1
1942 & 1953	Gambia	3	1	2	0
1945	Nigeria	4	0	3	1
1948	Portuguese Guinea	2	2	0	0
1949	East Bengal (Bangladesh), Malaya, Portugal	58	34	12	12
1950	North Borneo, Orissa (India), Tanganyika (Tanzania),	33	27	2	4
1951	Sudan, Hyderabad (India), Nyasaland Philippines, South Africa, Thailand	46	33	1	12
1953	Cameroon, Indonesia, Swaziland, Vietnam.	22	14	0	8
	Totals	***312***	***190***	***75***	***47***

Over the years the RRS has passed through several transformations in both management and research thrusts. Sustained research efforts produced useful rice cultivars and accompanying technologies for farmers in Sierra Leone and the entire West African region (RRS, 1998). By 1995, before the station was destroyed during the war, up to 33 RRS released varieties (the Rok series) were available in addition to the none-Rok accessions. Table 2.2 contains 25 of the most prominent of these varieties. In addition to rice, the station also included sorghum and other cereals into its research mandate in the later part of the 1980s when these crops were understood to be of vital importance to the local population. Research on the latter crops was entirely exploratory, including germplasm collection missions and field evaluations.

Table 2.2: List of rice varieties released by the Rice Research Station to farmers.
Source: Food and Agriculture Organization, Rice information, (FAO, 1997).

Variety Name	Ecosystem	Growth duration (days)
ROK 24	IVS	125-135
ROK 10	IVS	140-150
ROK 12	IVS	140-150
ROK 14	IVS	130-135
ROK 17	IVS	130-135
ROK 22	IVS	125-135
ROK 4	IVS	130-145
ROK 6	IVS	140-150
ADNY 2	IVS	not recorded
ADNY 3	IVS	variable
ADNY 5	IVS	not recorded
ROK 12	IVS	not recorded
ROHYB 4	Mangrove	130-145
ROK 22	Mangrove	not recorded
WAR 81	Mangrove	variable
WAB 96	Mangrove	130-145
ROK 5	Mangrove	130-145
CP 4	Mangrove	125 - 135
ROK 1	Upland	130-135
ROK 2	Upland	125-135
ROK 3	Upland	140-145
ROK 7	Upland	135-140
ROK 18	Upland	variable
ROK 19	Upland	not recorded
ROK 20	Upland	not recorded

2.3.2 The International Agricultural Development Programs (IADPs)

The IADPs were major institutional support programs for development work with farmers and were instrumental in the formulation of agricultural policies by the government of Sierra Leone within the period 1974 until 1979. They had external funding sources, involving agencies such as the World Bank, the European Union and the Overseas Development Administration (ODA) of the United Kingdom. During the later periods of the project, the IADPs were scattered all over the country with successful operations especially in the Koinadugu district (Jusu, 2000). The projects provided support to farmers for rice production in mainly the lowland ecosystems, and vegetable production in the same ecosystem after the harvest of swamp rice.

During the more advanced stages of program implementation, the Rice Research Station solicited the services of the IADPs for extension work in order to introduce their improved varieties to farmers. Field staff also conducted adaptive trials of rice varieties and multiplied improved lines for distribution to their farmers.

2.3.3 The West Africa Rice Development Association (WARDA)

The West Africa Rice Development Association operated as a sub-regional research unit in Sierra Leone between 1980 and 1993. The institutional objective was to increase the sustainable productivity of intensified rice-based cropping systems, with research focused on variety development for the mangrove swamp ecosystem. WARDA scientists realized that conventional breeding involving exotic rice varieties had not achieved much impact within the traditional farming system (Rhodes, 2003). Therefore, they exploited different rice genetic resources to develop, improve and adapt local varieties to the saline environments of the mangrove. WARDA also acknowledged that pure line selections from traditional landraces were most preferred as popular releases by farmers (WARDA, 2000). During its 20-year research period in Sierra Leone, WARDA released about 30 varieties in the entire West African sub-region. Further to this, WARDA scientists recently developed a new rice variety for Africa (NERICA), which is a hybrid between *O. glaberrima* and *O. sativa*, and this has opened up new horizons for rice cultivation in Sierra Leone (CGIAR, 2000; WARDA, 2000).

In 1997, a WARDA task force unit was incorporated into the newly established INGER-Africa program that was transferred to WARDA from IITA-Nigeria. Sierra Leone contributed to this project through variety improvement and appropriate management techniques that were developed by RRS rice scientists.

2.3.4 Adaptive Crops Research and Extension (ACRE)
This United States sponsored project conducted multiple on-farm trials in the 1980s on farmers' fields with both RRS-bred cultivars and advanced selections from within the traditional landrace populations (ACRE, 1986). They showed that superior genotypes selected from traditional landraces had higher adaptability and yield potential than the new varieties bred from exotic genetic resources.

2.3.5 Seed Multiplication Project (SMP)
The Seed Multiplication Project, Sierra Leone was a German-sponsored program that conducted large-scale multiplication of rice seeds and seeds of other crops in order to make quality planting materials available to farmers. The project also promoted economically viable production systems that introduced farmers to purchasing seeds and other agricultural inputs. Extension services were established that received fixed breeding lines (G0; G1) from the RRS, which were multiplied and made available to farmers. Variety distribution was conducted through demonstration farms and contract-farming schemes. Between 1987 and 1990, an average of 4700 contract seed growers benefited from this scheme (SMP, 1990).

2.4 Summary of the background of rice genetic resources

The case for focusing on the agricultural practices, which is defined in the predominant rice-based production system as starting with the seed systems, via the farming systems, on to the institutions that have contributed towards the extensive background of rice genetic resources in Sierra Leone, is presented. The chapter describes a stable system of agriculture, with emphasis on rice production and genetic resource management, which at any level could be and was disrupted by the events of the civil war. The key points highlighted therefore are as follows:

- Rice is regarded as the most important crop and source of calories in Sierra Leone, which makes it very well established in the agriculture and diets of the inhabitants of the country. Both cultivated species of rice, *O. glaberrima* and *O. sativa* are cultivated through a dynamic agricultural system that relies on the genetic diversity of the crop.

- On-farm practice for biodiversity management is conducted as a multi-layered cultural practice by farmers through which rice diversity is managed both between and within varieties, and cultivated with other crop species in variable and numerous agro-ecosystems. Rice genetic diversity is maintained within the concept of *in-situ* conservation and development.

- Rice is cultivated through various agricultural land-use agricultural systems known as the rice-based farming system that is characterized by two major sub-systems: the rain-fed upland sub-system and the hydromorphic lowland sub-system.

- Rice research and development, coupled with genetic resources introductions has a long history and a wide geographic background, and has been supported by major institutions including the Rice Research Station, the International Agricultural Development Agencies, the West African rice Development Association, Adaptive Crops Research and Extension projects, Seed multiplication projects.

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Chapter 3

Research methods employed in post-war rice genetic resource expedition in Sierra Leone

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3.1 Background

The 10-year long civil war in Sierra Leone caused significant additional deterioration of all agricultural systems and national biological diversity in an already desperate country that was under threat of severe environmental degradation (Squire, 2001). It resulted in the displacement of farmers from their traditional lands and caused them to live as refugees in other countries, or as internally displaced persons in their own country in situations where agricultural activities were hardly possible. Food production and the management of farm plant genetic resources came to a stand still for long periods in most parts of the country. This generated increased concerns for genetic erosion of major agricultural crops among the research community who were themselves displaced from their normal research locations. It was this concern that prompted the present investigation.

In the face of a gruesome war, this research sought to investigate the effect of war circumstances on the genetic resources of the nation's "king of crops", rice. Field expeditions were the only means to gather the needed information, and obtain rice samples. However, the expedition team was preparing to face communities that were less than 90 days from war; communities that had grown distrust for government officials, NGOs and anyone that appeared in decent clothing, and communities that were desperately hungry and in need of everything. The first problem faced in the preparatory phase was the method of data collecting, which had a lot of questions to answer such as: "Which locations to chose? How safe would these locations be? What sort of threats could possibly come up? How would the local communities respond to the expedition team? How was reliable information going to be obtained in the given desperate situation?" For answers, the research team consulted a number of published guidelines for genetic resources expeditions as well as the Technical Guidelines for Collecting Plant Genetic Diversity (BLM, 2005; Guarino *et al.*, 1995; Lawrence, 2002). None of these guidelines, however, gave a clue as to how to deal with guns, knives, hungry children and hostile host communities which were commonplace in all the districts during the time planned for the visits. There was therefore need to devise methods that could not only ensure the expedition teams' safety, but also offered the opportunity to obtain adequate samples of rice germplasm and accompanying passport data of reliable quality. The timing of the expedition and value of the information was also crucial – rice genetic resources was to be captured hot from the war situation, with little or no contamination from relief agency supplies, and the needed information directly from the farmer victims of the war. Given these circumstances, the expedition team had to face the challenge, guided by published technical guidelines, to devise sometimes "unconventional methods" in order to achieve the desired goals. The methods described below are a summary of the procedures that were employed.

3.2 Start of the program

The expeditions were aimed at capturing farmer knowledge about their rice varieties and at the same time collect all genetic resources of the crop in the possession of farmers. It involved collecting missions in combination with interviews and discussions with farmers in target villages (farming communities) in selected regions of Sierra Leone. A pilot visit was made in June/July 2003 to assess expedition needs and establish collaboration and linkages with other institutions that were interested in such research. The institutions that promised collaboration were the Ministry of Agriculture, the Rice Research Station (RRS) and the Cooperative for Assistance and Relief Everywhere (CARE).

3.3 Expedition team

The first phase of the research started in December 2003 and ran through February 2004. The Rice Research Station was not able to meet its commitment of providing the staff that was requested in June 2003 for the expedition. This was because the Stations administration was going through both financial and administrative challenges that were hampering all Station functions. The seriousness of the problem was that workers went for months without salary and all station activities were halted.

Despite of the above mentioned staff problem, the mission required people with sufficient educational background who were skilled at communicating with traumatized rural people and recording information into forms. Trained staff that could meet these requirements could be found at the University, the research stations and the NGO sector. These were, however, too expensive for us to employ. We therefore decided to get capable assistants from up-country where short-term contracts could be cheaper and workers more reliable.

Staff positions that were considered as permanent responsibilities for the entire collecting period are given below:
1. Interviewer: a high school teacher from Njaiama Sewafe, Kono District who had a background in conducting surveys and field data collection with NGOs on short contracts;
2. Records and documentation officer: a high school teacher and recent graduate from a teacher training college with a background of participating in the electoral commission in registering rural communities for elections;
3. Driver/mechanic.
4. Attendant: for cooking and miscellaneous activities during the field expeditions in Kono, Kabala and Kambia, January and February 2004.

The following persons were employed upon requirement of their services, either as a suggestion by the local authorities or as the situation required:
5. Security personnel: a leader of a strong local militia in Kono. He had strong support, but also enemies in some parts of the district. He stayed with us in December (for the preparations) and January (for the expedition in Kono).
6. Forerunner: a messenger for the Kono district expedition; month of January, a teacher and one of the sons of the paramount chief.
7. Medical personnel: a nurse, who also served as a forerunner in Kabala and helped with germplasm collecting; January and February 2004.
8. Interpreter: for interpreting Koranko, the ethnic language of Kabala, Koinadugu district.
9. Interpreter: for interpreting Temne, the ethnic language of Kambia district.

For the Kono District expedition we had to include local security personnel in the “training” discussions because of the security risks outlined to us by the authorities. We, however, had no need for translation as almost all the team members understood and spoke the Kono language.

In Kabala and Kambia no major concerns about security were raised, but we needed confidence building among the village communities. We understood from our contacts that most of the communities were disappointed with government officials and “NGO persons” who came to the village and made promises that were never fulfilled. We therefore used the services of the nurse in our team who had worked in the region for most part of the war.

Forerunners and interpreters were hired locally for the duration of the period we spent at each location.

3.3.1 Staff and personnel training/workshop

Because the team members were not familiar with germplasm collecting missions, we conducted a week-long training/workshop session before the actual field expeditions. The "training discussions" were held in December as an open forum within the team. It involved a review of communication methods with rural people (especially traumatized communities) in a post-war situation. Three resource persons were invited to share their experiences with the team, two of whom had experience working with war affected communities (one from a medical team at Canaught hospital who had conducted a medial survey during the war in the Western Area around Freetown, and the second from the CARE organization who had conducted food relief distribution to refugee camps). The third was an elderly man who had historic knowledge about tribal (civil) wars in Sierra Leone. We considered the following scenarios just in case we were faced with the situation:

- erratic and threatening behavior by community members who had distrust for NGOs;
- threatening behavior of a community member triggered by our own behavior or mannerism;
- armed robbery along some dangerous routes;
- unreliable information given by farmers;
- reluctance/refusal by farmers to donate seed samples;
- shortage of food, water and other essential commodities;
- unreasonable requests from farmers especially when these were put forward at the start of the session;
- unreasonable promises and commitments by the expedition team.

At the end of the discussions on these security/social issues, the scientific nature of the research was also presented. This included two proposed methods for interviews with farmers and seed collecting. The suggested interview methods were (a) personal (one-to-one) interviews with prominent farmers and (b) Participatory Rural Appraisal (PRA)(Ashby, 1994). Both methods involved open-ended discussions guided by pre-formulated discussion points that were outlined on the data form (see data collecting methods below). Protocols for seed sampling were also discussed with respect to handling, recording of data and labeling.

After the training session, a 3-day pilot expedition was undertaken in early January to test our methods and the skills of the team members. During this mission, previously anticipated social and security concerns became clear especially in the Kono district, which led us to revise our coping strategies. For example, we realized that the license plate of our vehicle was marked with an NGO plate, and the local community frowned upon this. Secondly, we learnt during the training/workshop that the entry of the team into remotely placed villages should carry a soft message – i.e., that the ladies should lead the group while entering villages, and the men should trail several meters behind. This would demonstrate to the traumatized communities that our group was not hostile. An extra precautionary measure was the service of the forerunner who prepared the way for our coming. We therefore decided to get the total involvement of the local authorities both at the planning stages and the actual field visits, based on the local situation in each of the three selected districts.

3.4 Points of entry and planning with authorities

Our point of entry to any of the locations was the major town closest to the area identified for the expedition. We were sure that these towns provided guesthouses, additional supplies and sufficient security.

3.5 Planning with local authorities

The first day of every expedition was spent doing the following:

i. visiting and consulting with local authorities – town chief, section chief, civil defense units, etc. With these people we asked for permission to enter the region and also obtained necessary information about dealing with the local people. We were often provided with additional personnel that sometimes became our guides, interpreters or forerunners, as the need arose.

ii. consulting with local technical staff who were familiar with the region for map reading and choosing villages according to our preferred scheme,

3.6 Choice of Districts, villages and farmers

Sierra Leone is a country that is divided into three provinces, with a total of twelve districts demarcated by clear national boundaries (Figure 3.1). Three districts were selected for this research, based on the following considerations:

i) the impact of the civil war in each of the districts. Knowledge about this was acquired from informal discussions with farmers and local militia leaders during the preparatory phases of the research,

ii) accessibility, with regards to security in the immediate post-war situation, and

iii) the geographic and ecological differences between the districts (Due and Karr, 1973; Stobbs, 1963)

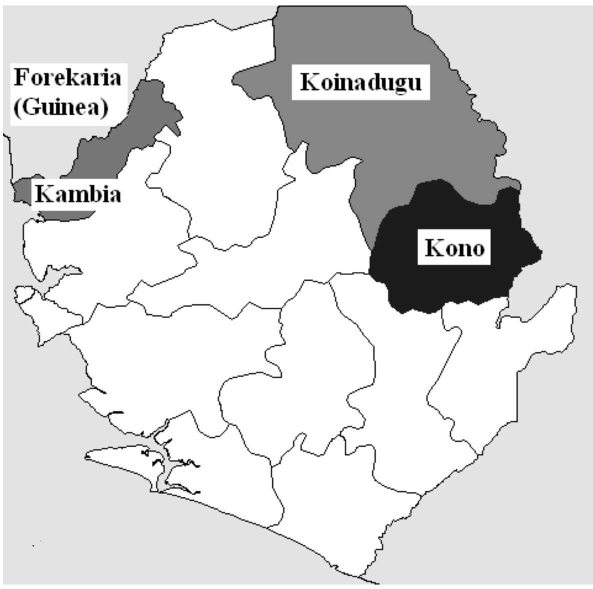

Figure 3.1: The map of Sierra Leone showing the districts selected for the research.

A fourth district, "zone frontière" of Forekaria in the Republic of Guinea was selected just across the border for the purpose of comparison between war-affected regions in Sierra Leone and the relatively more stable and adjacent region in Guinea. The Kambia district and Forekaria 'district' share the international border between the two countries, and they possess similar agro-ecosystems. Our assumption was that, due to active farmer-exchange of seeds that existed between farmers in these two districts during stable pre-war periods (Adesina and Zinnah, 1992), there is scope for comparison between the regions.

Border crossing protocols for the Guinea expedition followed international requirements, but because of the deteriorated security situation in Sierra Leone, Guinean authorities took extra precautions. A special team was put together to request permission from authorities on both sides, and this required travelling to the Guinea capital Conakry to meet with security officials and authorities of the ministry of Agriculture. Sometimes such missions took a number of days (a day's return trip under normal circumstances). A single border crossing during the expedition after obtaining all the required permission was also a painstaken exercise. See Appendix 2 for an idea of a single entry for the principal researcher alone.

The three districts selected in Sierra Leone were as follows:

i. Kono District - Eastern Province

Kono lies in the east of Sierra Leone. It borders Guinea in the east and Koinadugu district to the north, Tonkolili to the west and Kenema to the southwest. It occupies a total area of 5,398 km^2 and comprises fourteen chiefdoms. The district headquarter is Koidu town. The main ethnic groups are Kono, Mende, Kissi and Temne. Main economic activities include diamond and gold mining, rice growing, coffee and cacao plantations.

Much of Kono district is located on a plateau landscape covered with primary rain forest that receives a unimodal rainfall between July and September, with peak rains falling in August. High deposits of minerals including gold and diamonds also characterized the district. During the entire duration of the war, all fighting forces (the government which was backed by the West-African military forces, various mercenary groups and the local militia on one side, and the rebel forces on the other side) concentrated efforts on capturing and maintaining this district as a means of funding their respective campaigns. This led to prolonged occupation of the district as it regularly changed hands between the different military forces, and resulted in the displacement of the entire civil population. The first rebel incursion into this region took place in September 1992 (Peters, 2006).

ii. Koinadugu District - Northern Province

Koinadugu lies in the northeast of Sierra Leone. It borders Guinea in the north, Bombali district to the northwest, Tonkolili to the south and Kono to the east. It occupies a total area of 12,371 km^2 and comprises eleven chiefdoms. The district headquarter is Kabala town. The main ethnic groups are Limba, Koranko and Yalunka. Main economic activities include agriculture, cattle rearing and palm oil production. Koinadugu is the largest district in Sierra Leone with chiefdoms and villages situated miles apart.

The topography of Koinadugu district consists of plateaus and mountains, and is characterized by a Guinea Savannah climate, which is much drier than the climate in the more southern parts of the country and is most suitable for the cultivation of crops that are adapted to relatively dry conditions. Upland farming systems that supported such crops were predominant in this district before the war. The war reached this district in 1994 but the attacks, though intensive, were rather sporadic. Farmer displacement was not permanent and there was no prolonged occupation of the district by any of the fighting forces.

iii. Kambia District - Northern Province

Kambia district lies in the northwest of Sierra Leone. It borders Guinea to the north, Port Loko district to the south and Bombali district to the east. It occupies a total area of 3,016 km^2 and comprises seven chiefdoms. The main ethnic groups are Susu, Limba and Temne. The district headquarter is Kambia town. Main economic activities include livestock (small ruminants) and food crops (cashew nuts).

The Kambia district occupies a rather flat coastal terrain and is home to extensive mangrove and associated mangrove swamps that supports mangrove-based rice production. The region is home to the National Rice Research Station and to the headquarters of the Seed Multiplication Projects at Kobia, two institutions that deal directly with farmer plant genetic resources. The war reached this district in 1995, at the time when a number of peace agreements, however fragile had already been signed between the government and the rebel forces (Peters, 2006). Although rebels captured the region and actually held it for some time, massive destruction of property and killings were abated. In this situation, the farming community actually settled with the rebels, although sporadic attacks did take place.

In each district ten villages were selected in order to include both agro-ecological and cultural diversity within the districts, according to available ecological zoning data (Kamara, 1997a; Kamara, 1997b). The following criteria were adopted:

i. villages situated in regions with different ecological conditions defined by altitude and vegetation type, with preferred locations around hilly (in the Kono district) and mountainous regions (in Koinadugu district). In these two districts, however, strong considerations were given to the prevailing security situation. The Kambia District has a more homogenous landscape, and as a consequence villages were selected further away from each other to ensure a maximum of ecological variation. These pre-defined criteria for all three districts were based on the expectation of both ecological and cultural variation and the hope of capturing as much different rice types as possible to determine the differences.
ii. Villages were selected either in a circular or a T-shaped scheme, to ensure that sufficient geographical distance between any two villages occurred, while at the same time adjacent villages were close enough for a comparison of crop varieties. These schemes were designed to provide the basis for an analysis of genetic relations between village varieties.

3.7 The expedition

3.7.1 Kono district

The existing social and community situation in post-war Kono District was very different from the pre-war situation and also probably different from that of other parts of the country. Kono District holds the highest deposit of the country's natural mineral resources, including diamonds and gold. It used to be the most metropolitan of all the districts in the country, with residents including all tribes and foreigners. Because of the minerals, both the government and the rebel forces fought fiercely to maintain control of the District throughout the duration of the war. As a result, the District experienced some of the fiercest battles for control, which forced the entire civil population into complete displacement. According to a UN survey report, every single person in the district had experienced some sort of displacement, loss of relatives and property. The District Headquarter Town of several hundred thousand inhabitants, Koidu was burnt down to the last house. This sort of brutality leashed against the people warranted a strong civil defense unit called the ‘donsos’ (hunters) who mounted resistance against the rebels at one point, and later against the national army when the latter joined forces with the rebels.

After the war, the government asked the civil population to return home. Upon return, the indigenous citizens of Kono District were faced with another challenge. A much larger tribe from the North, the Temnes that make up 30% of the country had earlier infiltrated the district seizing major settlements. The Kono people found themselves paying rent for their rebuilt homes and market dues to the ‘foreigners’. This event forced the frustrated tribe (already embittered by experiences in refugee camps) to fight another bloody battle known as the 7-day-cutlass-war to drive out and/or subdue their tormentors. This happened barely 3 months before the present research.

Because of this occurrence, the more distantly placed communities in the area of our research were “very suspicious of ‘strange faces’ (as stated by local authorities). It added to the fully blown distrust for NGOs and government workers that already existed in the communities. This called for a special strategy to approach the farmers, which was worked out together with the authorities in Njaima Sewafe, the regional point of entry for us. Our strategy included:

i. to use the services of the civil defense commander we had employed. His fighters formed a large part of the now civilian population. We were, however, warned that this commander may not be welcomed in all the villages in the region. While he was considered a hero in one section, he was regarded a foe in another. This commander was not allowed to carry any weapon (although he was reluctant to leave his hunting gun behind) because it could make our mission look hostile;
ii. to use the services of a prominent member of the community who could be easily recognized by the villagers in the region. The individual (the son of the Paramount chief was chosen) acted as fore-runner (mostly on motor bike) to announce our mission in the selected villages before our arrival, and also to accompany our team especially in villages where the civil defense commander was not welcome;
iii. the female members of our team lead our way through the forests.

In most villages and settlements in Kono the community composition is largely metropolitan with mixed societies because of the diamond culture. Here the villages were selected using the circular scheme (odd circle) with three sub-clusters around the Nimini hills.

3.7.2 Koinadugu district

There is hardly a region in Sierra Leone that had not suffered gruesome events of the war, but the Koinadugu district suffered to a lesser extent than the Kono district. The wave of war reached the district in 1995, making rural communities to evacuate their villages and converge to the larger towns. Although no region was completely occupied by the rebels or the government soldiers, the communities were displaced, disoriented and also became hostile. The local militia known as the *Tamaboros* was very unpredictable and they had defense checkpoints in almost every village.

The civil defense commander that accompanied us in Kono could not come with us because he was deemed hostile to the unit in Koinadugu on the grounds of rivalry and territorial dominance.

At the planning table with the local authorities, we agreed that the nurse in our team, who had worked in the district for some period during the war, would be our forerunner. She would visit selected villages ahead of us and start with providing basic medical assistance to sick children. Two local technicians accompanied us and acted as security personnel, interpreters and confidence builders. The district headquarters, Kabala was our entry-point, and we used the T-shape scheme to select villages.

3.7.3 Kambia district

Of the three Districts, the Kambia District was the last to be reached and least affected on the scale of war destruction. The complicating factor here for us was that we had members of our team of Kono descent. We feared that the more remotely placed Temne tribesmen would be hostile to some members of the team. The second factor was that the communities here had been more exposed to visiting NGOs, some of whom had disappointed them. We had reason to be afraid because we had to enter almost all of the villages with our vehicle, which had a clear NGO registration plate. For some villages, the team had to leave the vehicle some distance away and continue the journey on foot. At the planning table, we decided to travel with two local technicians, one as our interpreter and the other as the forerunner and confidence builder. In the Kambia District, Rokupr was our entry-point. We used the circle scheme to select villages.

3.8 Data collection methods

A Participatory Rural Appraisal (PRA) was adapted from the Guide to Participatory Tools (Evans et al., 2006), characterized by pre-defined questions for general discussion sessions. Discussions were aimed at obtaining farmers' knowledge about their varieties, and the management of these varieties before, during and after the war. In the Kono District, the native language was used to communicate with the farmers, whereas in both Koinadugu and Kambia districts, interpreters were involved to translate the local Koranko and Temne languages.

Upon entering a village, we went through the traditional procedures of meeting the chief and his elders after which the team was introduced and the objective of the mission explained. The chief then summoned all the farmers that were present (already waiting because of the message of the forerunner) to the central meeting place – usually the chief's courtyard or house. The visiting team would then present a token as a "greeting-gift" to the community through the chief's spokesperson.

Following the opening rites, we then proceeded with discussions about the varieties the farmers were growing before the war, during the war and after the war. The adapted PRA method was used in this process guided by open-ended and pre-defined questions. In a series of discussion points, information was sought about the varieties the farmers had lost and the reasons for losing each variety. At the end of these discussions, they were asked to bring in samples of all the rice varieties that they cultivated in the village, together with the ones that they had just acquired. Seed samples were collected irrespective of the number of times a particular variety was repeated in the sample. The farmers often identified someone from within their ranks whom they agreed would be the most knowledgeable about their varieties, and he would give the names and other details of the varieties, with very frequent help from the other farmers. Members of the expedition team listed the varieties and took notes on other details. For each of the samples collected therefore, a collecting form (Appendix 1) was completed which detailed information including the farmer's name (owner of sample), variety name, vernacular name, meaning of vernacular name, date of collection, ecosystem, origin of initial seed, the duration of the variety when planted in the field and the number of years the variety has been with the farmer. Each of the accessions was carefully handled and placed in plastic bags, labeled and sealed. Each label contained farmer's name, village name and name of variety. Geographical coordinates and altitude were obtained using hand-held GPS and a standard altimeter.

Discussion sessions also included open dialogues with farmers wherein we recorded detailed knowledge about the war, about farmer displacement and the survival strategies in each region. Key informants were engaged in more structured discussions, and these were selected based on social positions in their respective communities and the extent of knowledge of the war and how it affected the local population. They included retired government officers, school teachers, civil defense commanders, and other prominent rural people who remained in the region for most parts of the war. Interviews were recorded both in writing and with an MP3 voice recorder. After interviews with the informants other people were interviewed as well and further contacts were made in case there was a need for further clarification of certain issues.

3.9 Back at base

Back at base, all general information obtained that day was cross-checked. Other members of the team sorted out the seeds collected and checked them against the collecting forms. A serial number was assigned to each accessory and this was recorded on both the seed plastic bag and the corresponding form. The list of accessions was then entered into the computer together with all accompanying data. Seeds that needed processing (e.g. extra drying) were treated separately. Accessions were assembled per village and placed in a separate bag.

3.9.1 Data entry and pre-analysis

Data storage and pre-analysis was performed using the Excel program of Windows NT. Data was entered by accession names in rows and data on accession features in columns. Accessions were sorted by origin, i.e. the sources from where farmers had first obtained them. Further analysis involved a study of the number of varieties that farmers had in their possession at the time of first collecting mission. All varieties reported lost by farmers were recorded based on village and district, and duplicate entries were recognized by name. The duplicate entries were stored as separate accessions for later analyses.

3.10 Follow-up visits

In December 2004, exactly a year after the first collecting mission, follow-up visits were made to the same villages with the objectives of verifying information about the samples initially obtained, to ask any additional questions where relevant, and to investigate new varieties that had been obtained since the first visit. During the verification visit a list of varieties was established representing those recovered by the farmers involved since the first collecting mission.

3.11 Field trends in 2003/2004

In all three districts, a total of 1056 farmers (311 in Kono, 236 in Koinadugu and 509 in Kambia) were involved in the PRA approach, from whom 6 farmers (2 per district) were key informants. In total, 289 rice accessions were obtained, 206 from the lowland ecosystem and 83 from the upland ecosystem. The distribution among the districts was as follows: 110 from the Kono district, 60 from the Koinadugu district and 119 from the Kambia district. Details about farmer information, passport data and rice varieties collected are presented in the chapters that follow in this thesis. The seed samples were used to obtain primary information about the varieties such as, the number of samples collected per region as given above, seed shape, color, aroma, etc. In 2004, all the samples were grown in field nurseries for multiplication purposes because most of the samples collected were of very small quantities. Qualitative morphological data was obtained for each sample in these nurseries. The following year, when seed quantities were large enough for a more statistical evaluation, the samples were grown in a field trial using the augmented design. The reason for this design was the large number of samples, and that individual seed samples were still not optimal to allow replication (see chapter 6 for details).

3.12 Discussion

For this research, field expeditions were inevitable, for they were the only means to gather the needed information, and obtain the rice genetic resource samples that were required for analysis. However, the gloom of war was affecting all sorts of post-war planning for most social and community-based organizations, as field agents fear that anti-political and anti-NGO sentiments on the countryside may turn into unprovoked violence against them. These two sentiments were not without reason because rural communities were not only disappointed with the government (for not providing enough protection during the war, and post war promises were not kept) but also with all types of NGOs (some rouges posing as NGOs had actually exploited the farmers for cash with promises of enlisting them for government food and seed supplies). Another complicating factor was that in the post-war situation, the farmers, especially in the Kono district were constantly worried about the repeat of atrocities, and this caused actual paralysis in all food producing activities.

It is important to note that the methods employed in this research followed comprehensive data collecting and skills for evaluating procedures with farmers as described in (Ashby, 1994). Extra procedures adopted were not intended to substitute for methodological, conscientious interviewing and sample collecting techniques, but to ensure security of the expedition team and to increase confidence of the farmers and respondents in order to arrive at the desired results. In addition, all precautionary methods were meant to ensure data quality through well defined procedures. It proved important to make the expedition staff understand that the primary objective of the mission was to ensure accuracy and completeness of data.

Interpreters and “confidence builders” were used to ensure that the expedition team conducted interviews of optimum quality. The most effective way this was done was to use the services of field workers highly experienced in conducting interviews. These workers, for example in the Kambia district, had previously conducted research activities with the farmers involved, and developed their own interviewing techniques. Where necessary, the expedition team made efforts to keep the staff within the objective of the current research. For this, the interviewer paid particular attention to the sequence of the interview process as a way to prevent omission of questions and make sure that interpreters followed a logical and systematic format for the interviews. This appeared to be crucial for a systematic acquisition of comparable and complete data, needed as the raw data for further analyses.

Concerning the actual acquisition of the rice samples, our methods deviated from the norm because instead of collecting subsets of the rice varieties present with the farmers (following sampling techniques), attempts were made to capture the total number of varieties in each region. Obtaining insight in all varieties of each region was an important objective of the present study, but was also necessary to be able to compare our results with the pre-war condition, when a similar total varieties inventory was performed. However, the possibility for collecting total varieties present with farmers was possible because of the comparatively low number of varieties that were found in each village.

3.13 Conclusion

This chapter has presented a general picture of the major data-collection activities during field expeditions conducted in an unusual situation. The data-collecting process has been outlined in sequence of procedures that were adopted as a consequence of the war situation at the time, and the insecurity associated with it. It discussed the risked involved, the staff, the specific confidence-building methods and the procedures for obtaining high quality and completeness of data. Also important were the type of information gathered, and the key functions and responsibilities of each expedition staff member. Right from the start of the preparations, it was clear that various procedures were necessary for the different situations experienced in each district, which in turn determined the specific approach that was necessary to ensure the acquisition of reliable and complete information. This included key informant interviews and the administration of the questionnaires, the choice of key respondents, and the data verification methods. The experiences gathered therefore lead us to conclude that in addition to conventional field procedures for conducting expeditions that involve collecting information and seed samples from farmers, specific situations may require innovative alternatives in order to obtain the desired results. We have reasons to believe that the expeditions have been successful in obtaining the anticipated results, but we are also convinced that this is due to the intensive preparations preceding the actual fieldwork.

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Chapter 4

An overview of the effects of war on farmers and their rice genetic resources in Sierra Leone

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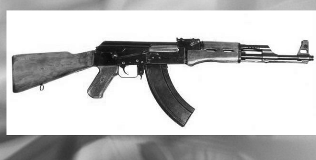

Abstract

This chapter analyses the effect of war on the farming communities in Sierra Leone and the rice varieties they possessed during and after wartime. It attempts to reconstruct the effects of the war from key information sources, which are not based on written versions of events, but on the stories from the victims themselves. The interviews were conducted in three districts, Kono, Koinadugu and Kambia, right after the war. The immediate picture that emerged was that the war affected each district differently, which had therefore required different survival strategies of the farming communities. The Kono district experienced heavy fighting and suffered total displacement of farmers for long periods, and after the war these farmers had to rely on seeds mostly obtained from outside their own region. However, the district that suffered the greatest seed losses, along with the loss of an entire farming system was Koinadugu where fighting had been sporadic and unpredictable. As a consequence post-war seed recoveries in this district were slow. Though the Kambia district was actually occupied by the rebels, the farming communities were not totally displaced. Amidst intimidation and massive looting of large seed stores, the highest number of varieties survived here when compared to the other two districts. In all three cases, the traditional seed systems remained invaluable, both during and after the war, for the restoration of farmers' varieties. Finally, the need for government and relief agencies to first understand the nature by which farming communities and their seed systems were affected by the war, coupled with understanding the seed needs of the farmers before attempting any seed relief is highlighted.

Key words: farmers, war, rice, varieties, seeds, genetic resources, Sierra Leone.

4.1 Introduction

For many decades, agriculture is the main production sector of Sierra Leone, employing two third of the labour force. It is also an important economic activity accounting for 50% of the national Gross Domestic Product (GDP) (Deen, 1972). Rice is the most important agricultural food crop and is cultivated by farming communities, most of whom are living in marginal environments and often very difficult socio-economic conditions (Steady, 1985). Great social importance is attached to rice cultivation, which represents a way of life in which traditional values are embedded (Beoku-Betts, 1990). Maintaining crop diversity in order to ensure yield stability and food security is part of such traditions and values. Any disruption of the production cycle inevitably disrupts food security and farmers' livelihoods, and at the same time threatens the on-farm survival of genetic resources.

Conservation of agricultural biodiversity (agro-biodiversity) is considered a vital component of maintaining agro-ecological systems (Wood and Lenné, 1999). Agro-biodiversity is supported by diverse ecosystems to which different cropping systems and indigenous knowledge are adapted (de Boef, 2000; Shrestha, 1999). Rice diversity in Sierra Leone is part of a variety of such cropping systems, that can be grouped in two main categories: 1) rain-fed upland cropping systems (characterized by forest transition zones, savanna lands, plateaus, hill slopes and mountainous terrains), and 2) lowland cropping systems (characterised by water-logged swamps, inland valleys, riverine grasslands, bolilands, mangrove and associated mangrove swamps, all exposing the rice crop to different water regimes). Such diversity in ecosystems provides a natural basis for a high level of agro-biodiversity (Almekinders and de Boef, 2000).

Sierra Leone lies within the West African belt of the African rice species *Oryza glaberrima* Steud. (Portères, 1970). Genetic diversity of this rice species and its ecological relevance is evident from the presence of its ancestral wild relatives *O. barthii* A.Chev. and *O. longistaminata* A.Chev. & Roehr. in several regions of the country. Between the 15th and 17th centuries, traders introduced the Asian rice species, *O. sativa* L., into West Africa, which has spread throughout the region. Nowadays, both *O. glaberrima* and *O. sativa* are widely grown by farmers in Sierra Leone, often in mixtures, whereby natural inter-specific crosses between the species has been reported to occur (Jusu, 2000). In recent years, high yielding inter-specific hybrids of the two species have been developed by scientists at WARDA giving rise to promising new varieties known as the "new rice for Africa" (NERICA), which are being included in the rice systems of Sierra Leone.

In the last hundred years, however, deforestation and other land degrading factors have had negative impact on rice cultivation systems through the loss of natural ecosystems in the country (Davies, 1987; Teleki, 1980). In addition to this, the most devastating single factor in the last two decades presumed to be responsible for negative impacts on both agro-biodiversity and natural biodiversity has been the civil war, which started in 1991 and lasted for 10 years. It had devastating effects on all production systems nationwide, and was detrimental not only to human life, but also to national infrastructure, natural habitats, and agricultural systems. As a result, the entire crop production sector in Sierra Leone was crippled since many farmers were forced to leave their homes with barely anything to carry (Squire, 2001).

The consequences of wars on global biodiversity have been widely published (Martin and Szuter, 1999; McNeely, 2000), with more recent attention to the African situation (Brown, 2006; Richards, 1998; Richards *et al.*, 1997). Long lasting civil wars in Africa are known to have led to extensive loss of habitat and agro-ecosystems and also contributed to the destruction of wildlife and protected vegetation (Jacobs and Schloeder, 2001; Kalpers, 2001; McNeely, 2000). Similar effects have been described for the civil war in Sierra Leone, particularly in relation to the ecosystems upon which traditional rice cultivation in the country depends (Squire, 2001). However, the threats to farmers themselves and their agricultural systems, together with the overall consequences on agro-biodiversity leading to the erosion in farmers' seed stocks, have hardly been directly investigated or reported. This is because war effects on rural farmers are generally presented in numbers displaced. The secondary effects on agro-biodiversity are probably considered less important than the more visible government-conscious trade and other economic interests.

Researchers of the National Rice Research Station (RRS) in Sierra Leone feared that the effect of the war on farmers and their seed systems could be substantial and the possibility of genetic erosion was considered high, because many farming communities were totally displaced and often lacked the ability to grow rice for several seasons. The concern of the research community was therefore directed at the possibility of loss of on-farm genetic diversity resulting from the disturbance caused to farmer communities. A similar situation occurred in Rwanda (Richards and Sperling, 1999). Further to this, the specific manner by which the disruptions occurred during the various stages of the war is also of vital importance. The overall seed exchange system that was once robust needed to be investigated: whether it totally failed under stress, or did prove strong in order to allow for rapid post-war seed rehabilitation (Scowcroft, 1996; Sperling, 2002). In this study, the emphasis is on war-related events and their effects on the genetic resources of rice in Sierra Leone, by investigating how farmer communities in different regions were affected and reacted.

4.2 Materials and methods

4.2.1 Field visits

The first major consideration for this research was to outline the phases of the war and how these affected farmers in the different districts being studied. The main focus was to understand the nature in which the conflict affected farming communities, and the resulting effect on rice biodiversity. In order to get a complete coverage of events, it was investigated how farmers' normal lives were disrupted, starting with collecting key informants' stories for each district. Some instructive excerpts from the reports are presented below. Besides that, rice samples were collected from farmers in their villages along with passport data. This information was entered into Excel sheets for analysis, which is described in the section below. For details on the field expedition, including the choice of study sites, methods used for interviews with farmers and key informants, sample collection, information documentation, and data verification methods, see chapter 3.

4.2.2 Data compilation and analysis

For all data compilation, the Excel program for Windows NT was used. Passport data was entered for each accession including farmer name, name of district, village and date. It also included features of rice samples such as variety name and the ecosystem where it was grown. Two lists were made for each village, one for the available varieties and the other for the varieties that were reported lost. A first control was conducted by sorting by village and comparing the lists of varieties reported present and those reported lost. The sample names that appeared in both lists were removed from the "lost" list and classified as "present". Following this, the variety list for those accessions that were present with farmers was pooled together for each district. Duplicate names were identified but not eliminated. The lists of "lost" varieties were also pooled together and compared with the pooled list of "present" varieties. By doing this, cross references were made in order to identify the varieties that were declared lost in one village but were present in the other. This enabled us to arrive at three separate lists per district: i) varieties that were actually present; ii) varieties that were reported lost in one place but present elsewhere; and iii) the varieties that were completely lost. This procedure was repeated for all three districts and varieties with similar names between districts were identified in each list.

Following this, the accession lists were sorted by their origins, or rather the sources from where the farmers had first obtained them. Further sort functions involved compiling the accessions by village and district, and the number of farmers who possessed more than one variety at the time of the first collecting mission. In this process, varieties that were reported lost by farmers were sorted by farmer, then by village and finally by district. In order to obtain the final number of varieties that had been completely lost, duplicate varieties determined by name were eliminated from the list, and the remaining varieties, all with a single entry, were counted.

4.3 Results

Below are highlights of the interviews that were conducted with key informants.

4.3.1 Kono district

The first interviewee in the Kono district was a retired agricultural extension agent, 70 years old at the time of the interview in 2003, with a high-school education background.
“ *… we (in the Kono district) experienced the war in phases: first, second, third until we could not count anymore and the entire district was occupied for a long time. The very first RUF incursion occurred in September 1992 while I was still in the district head quarters, Sefadu. It started with sporadic shooting and indeed scores of people were killed. Initially, we thought we could confront the rebels through civil resistance, but they came with massive force and lots of weapons. We did not have weapons. The first attack (this we later referred to as the first phase, as we started counting later on) was short lived as the government forces uprooted the rebels a few weeks later. After this, each succeeding incursion in sequence was more brutal than any of the previous ones, and it led to massive killings and the exodus of people being displaced by the offensive against the RUF rebels by the troops loyal to the government. I was forced to move to my village, Teiko, which is situated along the Freetown – Kono highway. Upon arriving, I saw a massive exodus of people evacuating the district and heading in the Freetown direction. It was after the third attack on the district that I decided to finally evacuate my family and we settled in Majendu in the Mende region towards the south”(*Sahr Johnbull, Key informant, Teiko village, (2003)).

The second informant was a local militia leader, 25 years old who made his name from his fierce stance against the RUF rebels and who defended his region from insurgent attacks.
“The RUF rebels first entered the Kono district with Sefadu as their target in September 1992 and they were repelled by the government forces within days. At that time the civil population was displaced only for a short while, and although there were massive killings, most people returned to their homes afterwards. Our region here was unaffected at first because we are miles away from the regional headquarter town, Sefadu. After the first insurgent phase, the rebels regrouped for the second time and in November 1992, they attacked again and this time government forces were no match for them. The West African forces (ECOMOG) had to come late November, and again the rebels were uprooted. All of this happened at great costs to civilian lives and property. Our community here at Maduya was attacked at night during the second attack, and the entire village was evacuated and most of the residents sought refuge in Punduru, a village in the Mende tribal region south of here. I evacuated my family and all dependants to the Mende tribal regions around Kundoma where the Kamajos were active and provided some sort of security. It was after we had moved most of the residents out of danger that we returned to join the civil defence movement, the “Donsos” forming a defence force against the RUF rebels. It was then that the government forces, backed by the West African regional forces (ECOMOG) and South African fighters battled the rebels for control of the district. Together with my militia commandos, I fought alongside the government and mercenary forces to protect our land. Repeated RUF incursions kept us busy, and sometimes fighting lasted for many days and weeks which led to the total evacuation of the entire district – people were flowing in a stream along all the major roads heading for safety.

Because of the viciousness of the attacks, no one can even think of rescuing anything of value, not even farm seeds, not to mention practicing agriculture. I must mention that during the previous evacuations, some farmers brought seed with them. During the final evacuation, no one could bring anything along. Most farms were left unattended and everybody lost his/her farm. Almost all of us in this village were farmers and we lost all our seeds (Sahr Lebbie, master farmer and local militia leader, January (2005)).

4.3.2 Koinadugu district

The key informant here was a senior member of the community and had worked as local staff for the Christian Relief Services (CRS) who were in operation in the district at the time of RUF rebel incursion. *"... we were in our village in September 1994 with lots of goats and sheep, living a peaceful life when the RUF rebel factions attacked. They first drove us out and looted several items from our homes, including food and clothing. They ravaged our stores and took away everything including what we kept for seed. We ran away and into the nearby forests where we stayed for sometime while others sought short-time refuge in nearby villages where the rebels had not entered yet. Almost everyone returned to their homes when the rebels moved out. After about six months the second incursion occurred, this time the rebels resided for up to five days in our village. On the fifth day, they were dislodged by the Guinean troops. One week later, we were attacked again, this time the rebels resorted to burning down houses, stores and entire villages. Whenever they attacked, the community moved to the forests. It was clear that they were not coming after the civilians, except when they needed food items desperately - they would kill anyone who got in their way. Some people stayed in the bushes for long periods and could grow some swamp rice; others moved from one safe village to the other, according to the trend of attacks. During this time, some of us moved on to Kabala and there was nothing to live on. For the most part, neither the RUF nor the government forces resided in the region. The rebels would only hit and then move to other regions. On their trail, they captured residents and forced them to thresh and prepare food for them. Left-over rice was burnt and so were houses and stores. This discouraged most people from returning to the villages again, so they resided in the bushes. As for our seeds we lost so much. The attacks were almost always during the time of harvests, or soon after. Only once it was mid-season and we had to run and left the farms unattended. Although I used to work for the CRS, since the start of the attacks when the regular operations were stopped, no seeds have been supplied in this village, not during the war, and until now nothing have been supplied yet…*" (Mohamed Wulereh, informant, January 2004, Mamaduya village).

The second informant in this district was a community leader, the village chief. *" At about 1998, long after the year's harvest and storage, the rebels attacked our village. At that time, our rice on the field was near maturity. We went hiding in the nearby forests, and quietly we did come out to visit the fields. The rebels were not staying in the villages because they feared the civil defense forces (the Tamaboro), and the Guinea soldiers. However, they were also watching the rice fields and at the time of harvest, they conducted the harvest. Their strategy was mostly hit and run, and they came at all times – sowing, harvest and any odd time. They would eat everything, including what we kept for seed. What they could not eat or carry, they burnt. This village was burnt much later, when the Guinean troops forced the rebels out. Over the years the entire region suffered several attacks, often at the time of harvest, and this caused insecurity within the local community. Most of us resided in the forest and grew rice in the forest swamps. Upland agriculture was impossible because it would have involved bush burning, which attracted roaming rebels to hiding places. Moreover, upland agriculture is labour intensive and this was not suitable in the situation we found ourselves"* (Amara Dabo, Nyanfrandor – tribal head – through translator – 2nd January 2005)

4.3.3 Kambia district

The Key informant in Kambia was the Farm Manager at the Rice Research Station (RRS) who stayed in the region during the time the district fell to the RUF rebels. *" ... by the time the war reached the Kambia district, precisely in January 1995, the intensity of atrocities against the civilian population was at its lowest. A number of peace talks had been held between the government and the rebels, and much of the killing of innocent people had stopped. Because of this, many farmers actually stayed with the rebels in this district, though it was like living through nightmares of molestation and abuses. Some of the farmers that stayed had to give a good portion of their harvests to rebel leaders as a fee for protection. Other people had to pretend that they were part of the RUF revolution and sympathized with their views as a survival strategy.*

However, the RUF were very unpredictable and could change from friend to foe within seconds. The civilian population was aware of this, and especially at times when food rations of the fighters were running low. Whenever they ran out of food, they attacked, and the strategy in the region was mostly erratic which created shock, distress and fear to the community. By the middle of the growing season of 1995, there was a sort of total standstill during which no production activity was possible. All seed distribution, multiplication and management activities were disrupted. Most of the farmers lost their varieties earlier supplied to them by the RRS.

One example of an event when farmers lost their rice stock took place in February 1999 when the rebels attacked Rokupr Township and the surrounding villages without notice. Farmers who had cultivated their crops in secret places had good returns and were processing and storing their harvests. The offensive was so fierce that it came to a situation where the farmers had to choose between their lives and their harvests. All the farmers had to let go and allowed the rebels to loot whatever they could lay hands on, including their harvested material.

The rebels threshed the looted rice with no regard for seed, and everything regardless of variety difference was stocked together and used as food. Such was their strategy, especially when they set out on missions to obtain food to support their forces elsewhere. The most hideous destruction to seed was that they set fire to whatever was left over. Stores and houses were burnt down as a way of punishing the farmers because the RUF alleged that they (the farmers) were working under the auspices of the ruling government.

*Another devastating incidence was when the rebels somehow got information about the huge seed stores both at the Rice Research Station and at Kobia. This was a rich find, and the rebels took weeks to empty these stores, using huge trucks to transport the seed materials to other regions in the country where their leaders and fighting forces were. (*Conteh, Farm Manager, Rice Research Station, Rokupr, 2004)

Details about the number of farmers in relation to the rice samples collected per village in all three districts are given in Tables 4.1, 4.2 and 4.3 for Kono, Koinadugu and Kambia respectively. Though the Kambia district had the highest number of farmers when compared to the other two districts, it also had the lowest percentage of farmers that possessed seed in the immediate post-war situation. However, the number of rice samples collected in the Kono district was comparable to that collected in the Kambia district, though the number of varieties in the Kambia samples was much higher than those in the Kono samples. The Koinadugu district had the lowest number of samples and varieties and all the samples collected were reported to be lowland ecotypes (see chapter 5). Despite these differences, it was observed that the percentage of farmers with 1, 2 or 3 varieties was comparable for all three districts.

Farmers reported losing most of their varieties and in some cases entire seed lots as a consequence of the war, and the data for the three districts in Tables 4.4, 4.5 and 4.6 confirms this. Because the selected villages were of different sizes, and as a consequence may have had different number of varieties before the war, it was difficult to make clear comparisons in terms of the proportion of varieties lost.

Tables 4.1, 4.2, and 4.3: Number of rice samples in possession of farmers during the first year after the war

Village	No. of farmers	Farmers with seeds	No. of samples	No. of varieties	Number of farmers in possession of			
					none	1 var.	2 vars.	3 vars.
Table 4.1: Kono								
Basaya	45	4	10	7	41	1	1	2
Bendu	62	20	28	22	42	14	5	1
Gbetema	28	9	12	10	19	7	1	1
Maakor	16	4	6	5	12	3	0	1
Maduya	25	8	9	8	17	7	1	0
Peya	18	5	10	7	13	3	1	1
Taibor	8	4	5	4	4	3	1	0
Teiko	46	6	11	7	40	2	3	1
Tembedu	58	10	17	16	48	4	5	1
Teoma	5	2	2	2	3	2	0	0
Kono total	**311**	**72 (23%)**	**110**	**35**	**239 (77%)**	**46 (15%)**	**18 (6%)**	**8 (3%)**
Table 4.2: Koinadugu								
Kasompe	11	2	3	3	9	1	1	0
Katombo II	21	7	8	6	14	6	1	0
Koromasilaya	18	4	5	4	14	3	1	0
Korekoma	44	4	6	6	40	3	0	1
Makakura	12	8	10	6	4	6	2	0
Malaforiya	15	3	6	6	12	1	1	1
Mamuduya	22	2	6	6	20	0	1	1
Nyaforandor	23	3	5	5	20	2	0	1
Senechedogou	34	7	8	6	27	6	1	0
Yagala	36	3	3	3	33	3	0	0
Koin. Total	**236**	**43 (18%)**	**60**	**26**	**193 (82%)**	**31 (13%)**	**8 (3%)**	**4 (2%)**
Table 4.3: Kambia								
Bamoilol	65	15	28	26	50	6	7	3
Funkuya	43	2	4	4	41	1	0	1
Gbonkomaseseh	33	7	15	15	26	2	3	2
Kamba	34	15	18	18	19	12	3	0
Kania	23	8	9	9	15	7	1	0
Magbema	28	7	10	10	21	4	3	0
Mbain	54	3	5	5	51	2	0	1
Rotain	56	7	10	9	49	6	0	1
Sendugu	75	8	12	11	67	7	0	1
Senthai	98	6	8	8	92	4	2	0
Kambia totals	**509**	**78 (15%)**	**118**	**59**	**431 (85%)**	**51 (10%)**	**19 (4%)**	**9 (2%)**
Totals for all three district								
Grand totals	**1056**	**193 (18%)**	**288**	**119**	**863 (82%)**	**128 (12%)**	**45 (4%)**	**21 (2%)**

However, considering the total numbers of varieties for each district, it is apparent that the highest losses were experienced in the Koinadugu district, followed by the Kambia district. Farmers in the Koinadugu district explained that major losses occurred during the first two growing seasons after the initial rebel incursions, when rebel attacks were more frequent and unpredictable.

Tables 4.4, 4.5 and 4.6: Number of varieties reported lost per village within a 15-year period, including the war years and the 1st year post-war recovery.

Table 4.4: Lost rice varieties in Kono

Village	Lost due to war	other reasons	recovered yr 1	% recovery
Basaya	22	0	10	45.5
Bendu	17	0	9	52.9
Gbetema	19	1	10	52.6
Maako	13	2	3	23.1
Maduya	15	0	5	33.3
Peya	28	10	11	39.3
Taibor	15	0	8	53.3
Teiko	17	1	4	23.5
Tembedu	38	3	15	39.5
Teoma	14	0	3	21.4
Total	**72**	**17**	**38**	**52.7**

Table 4.5: Lost rice varieties in Koinadugu

Village	Lost due to war	other reasons	recovered yr 1	% recovery
Kasompé	24	2	3	12.5
Katombo II	13	0	6	46.2
Koromasilaya	21	1	4	19.0
Kurekoma	10	5	6	60.0
Makakura	18	7	7	38.9
Malanforiya	37	0	8	21.6
Mamuduya	17	5	9	52.9
Nyafrandor	25	0	7	28.0
Senekedugou	17	8	4	23.5
Yagala	13	5	7	53.8
Total	**96**	**21**	**43**	**44.7**

Table 4.6: Lost rice varieties in Kambia

Village	Lost due to war	other reasons	recovered yr 1	% recovery
Bamoilol	29	1	24	82.8
Funkuya	20	0	5	25.0
Gbonkomaseseh	17	0	14	82.4
Kaamba	23	0	14	60.9
Kania	29	2	13	44.8
Magbema	17	0	10	58.8
Mbain	9	1	6	66.7
Rotain	18	3	12	66.7
Sendugu	17	0	12	70.6
Senthai	20	1	9	45.0
Total	**88**	**8**	**19**	**21.5**

The results of variety recovery activities by farmers during the first two farming seasons after the cessation of hostilities are also given in Tables 4.4, 4.5 and 4.6. It emerged that within this period, a substantial number of the varieties initially reported lost were recovered. The highest recovery was reported in the Kambia district, followed by the Kono district, with the Koinadugu district also showing high recovery potential. It was clear from comparing villages that the variety recovery process was not uniform for all villages because each village experienced losses to different degrees, and information about variety availability was rather strategic to farmers. We learnt from all the districts that the farmers first try to hold back information about sources of certain varieties until they were able to retrieve the varieties for themselves. Only then would they share the information, or the varieties themselves with neighbours and friends. In the Kambia district, most of the varieties recovered were obtained from neighbouring (other) villages. In Koinadugu the highest number of varieties was obtained from their relatives (Kin), while in the Kono district, the highest number of their varieties was obtained from outside their region (Table 4.7). Some examples of the varieties that were reported lost in one village but could be found elsewhere in the region are given in Table 4.8.

Table 4.7: Details of variety recovery per district.

Source	**Kono (n=110)**	**Koinadugu (=60)**	**Kambia (n=119)**
Kin	22	25	23
Other village	4	13	40
NGO	8	6	0
Government	3	2	0
Market	4	8	7
Exchange	19	2	16
RRS	0	1	17
Kobia	0	0	6
Other regions	48	0	3
Not sure	0	1	2
Own seed	2	2	5

4.3.4 Seed relief options

It was difficult to verify government intervention into the variety recovery efforts of farmers during the course of the war because the seat of government changed hands at least 5 times during the 10-year period, and each administration had its own policies towards agriculture. However, as an example of government intervention in post-war seed rehabilitation efforts, it serves to mention that the Ministry of Agriculture of the last government that brought the country to peace organised farmer groups known as Agricultural Business Units (ABU) through the Farmer Field School (FFS) approaches of FAO which conducted seed multiplication and devised distribution channels for selected varieties (ABU, 2004; FAO, 2007). Members of the ABUs received a number of varieties from government extension agents, and reported their returns to these agents who in turn reported to the Ministry. This set-up encouraged competition between different ABUs within a region, and with other regions, which encouraged them to be more aggressive in seed multiplication of the varieties supplied.

In all three districts, there were reports that a number of relief agencies collaborated well in producing seed relief in combination with food relief to farmers in safer areas during the earlier parts of the war. Some Community Based Organizations (CBOs) and Non-governmental Organizations (NGOs) received funds from the World Bank and other donor agencies in order to give them the financial means to accomplish this goal. The most active CBOs, especially in the Kambia district were the Kafonka Farmers Association (KAFA), the Farmers' Seed Association (FSA) and the Christian Farmers Association and Development Agency (CFADA), who purchased local seeds, multiplied them on contractual basis and distributed them to displaced farmers. However, at first, farmers were not sure about the source of the seeds because they thought they were foreign materials. Furthermore, the seeds were often distributed during off-season periods, so past planting time. In such cases, the distributed seeds were generally consumed as food. NGO activities however came to a halt when the war intensified by the end of 1995, and many foreign aid workers had to leave the country (Squire, 2001).

Table 4.8: Examples of varieties reported lost in one village but present in another village

District	Variety	Reported lost in:	Present in:
Kono	Donsobofeo	Peya, Basaya, Teoma	Bendu, Maduya, Teiko, Tembedu
	Gbeapui	Bendu, Tembedu, Gbetema, Maako, Taibor	Basaya, Peya
	Gbekedu	Teiko, Gbetema, Peya, Tembedu	Bendu
	Ndwiwa	Teiko, Basaya, Gbetema, Maako	Peya
	Sandebei	Gbetema, Basaya, Taibor, Maakor, Tembedu, Peya	Basaya, Bendu
	Yonjrowa	Tembedu, Peya, Teoma, Basaya, Gbetema, Maakor	Bendu,
	Yabassie	Bendu, Maako, Maduya, Teiko, Tembedu, Basaya, Teoma, Gbetema	Peya, Teibor
Koinadugu	Gbelemayaka	Senekedugou, Koromasilaya, Mamuduya, Malanforiya, Nyafrandor, Katombo II, Makakura Kasompé	Yagala
	Soronkadi	Makakura, Korekoma	Senekedugou, Koromasilaya
	Sinuwa	Malanforiya, Mamuduya, Koromasilaya, Nyafrandor, Kurekoma, Yagala, Makakura, Kasompé	Senechedugu
Kambia	Pb Bop	Rotain, Funkuya, Sendugu, Magbema	Gbonkomaseseh, Bamoilol
	Pa Bundu	Funkuya, Kania, Bamoilol	Sendugu, Rotain
	Pa Buttercup	Kamba, Gbonkomaseseh, Magbema	Kania, Bamoilol, Rotain, Mbain
	Pa Salayforeh	Rotain, Kaamba, Bamoilol, Magbema, Kania	Kamban
	Pa yangbasay	Funkuya, Kamba, Rotain	Gbonkomaseseh, Kamba, Sendugu, Gbonkomaseseh, Bamoilol
	Pa Yenet	Rotain, Funkuya, Sendugu, Kaamba, Bamoilol, Gbonkomaseseh	Rotain, Bamoilol, Gbonkomasenseh
	Gbasisyin	Kamba, Kania	Magbema, Sendugu, Gbonkomaseseh, Bamoilol, Mbain, Senthai, Bamoilol
	Pa Temne	Rotain, Funkuya, Sendugu, Kaamba, Bamoilol, Gbonkomaseseh, Mbain	Gbonkomaseseh
	Pa DC	Rotain, Senthai, Gbonkomaseseh, Rotain, Sendugu, Kaamba, Senthai, Mbain	Bamoilol

4.4 Discussion

The reports on the civil war by farmers and key-informants in the districts studied provided some basic understanding of the manner in which agriculture in each district was affected and how both the lives of farmers and agriculture were disrupted. The information also provided an opportunity to interpret how the war progressed and affected agricultural activities, although no direct link to on-farm maintenance of genetic resources was obvious in some cases. Our first observation was that the overall effects on farmers and their agricultural biodiversity were not identical in the different regions. The final outcome for each region was therefore determined by the nature and duration of insurgent activity and the overall consequences on rice genetic resources. A similar assessment was made by Sperling (1996) on the Rwandan war. Below, an overview of the effects of war in the study regions in Sierra Leone is presented.

4.4.1 Kono District

The development of the war in the Kono district presented a case in which economic interests contributed to the total disturbance of agriculture and seed maintenance. The Kono district is rich in minerals (diamond and gold), and therefore became the most contested region between the government, the Revolutionary United Front (RUF), and mercenary groups that were brought in by each of the two main parties. Both the government and the RUF movement needed access to the mineral resources to finance their side of the war. This created a drive for financial resources and led to a situation that is naturally a strong factor in warfare (Bourguignon, 1999). As a general effect, the Kono District was exposed to vicious, frequent and prolonged attacks and counterattacks between the opposing forces, which over a period of time led to the total displacement of the entire civilian population. Naturally, this caused the farming systems to stop functioning and a concomitant loss of planting materials at the farm level took place. Most of the displaced farmers sought refuge amongst their southern neighbours, the Mende tribe whose regions were defended by a powerful local defense force known as the *Kamajos*.

Notwithstanding this total disruption of agriculture during the war, the number of rice samples collected from the Kono district presented evidence for a strong return of diversity maintained in the district’s rice agricultural system. Some of the collected samples were identified as types that were grown in the region before the war, but the vast majority of varieties had been obtained from elsewhere. Farmer information showed that there had been absolutely no agricultural activity in the entire Kono district during the course of the war. The farmers who possessed rice samples at the time of our visit could therefore be distinguished in three categories:

(i) returnees coming home with seeds originating from their areas of refuge. The newly introduced seeds were obtained from host farmers who had provided a “home” for their displaced colleagues. The displaced farmers in turn worked on the farms of their hosts for periods ranging from 2 to 8 years. For the displaced farmers, farm labour had been a survival strategy by which they received security, food and seed in return.

(ii) farmers who had fled with their own seeds and returned from refugee camps with these seeds. It appeared that the early-displaced farmers who saw no quick solution to the conflict adopted production and variety maintenance strategies in the safer regions where they had sought refuge. They had time enough to grow, maintain and save some of their seeds from loss. Years of settling in relative safety enabled these farmers to cultivate not only their seeds, but also the accompanying traditional and cultural practices. Such activities during war are described by Collier (1999) as a sort of disinvestment in the conflict region leading to diversion of assets (seed in our case) and maintaining these assets over the course of the war.

(iii) returnee farmers who had few or no seeds and had to invest time to look for planting materials. These farmers obtained varieties from villages both nearby and far away. Virtually every returning farmer was engaged in this activity to varying degrees because seeds of many varieties were still very scarce within every region. The recovery process led to a situation in which farmers could regain more than half of their lost varieties within one year. Reports showed that some of the farmers traveled to very distant regions just to get a handful of seed for their farms.

4.4.2 Koinadugu district

The Koinadugu district presented a war scenario rather different from that of the Kono district. There was no direct economic interest for the rebels to hold the district except for gains from looting and to facilitate search for food by mobile fighting bands. Full-fledged effects of the conflict reached this region only during the fifth year of the war, during which time the rebels had adopted a new military strategy, consisting of infiltrations and pinprick attacks that were conducted by mobile units (Squire, 2001). According to farmers, rebel insurgencies were sporadic, and swift, conducted on a hit-and-run manner. Both the rebels and government forces had no intention of holding ground for a powerful local militia and Guinean forces prevented them from doing so. The effect on the general population and farmers was heightened insecurity, although the intensity of attacks did not warrant complete evacuation from the region as it happened in Kono. However, the sporadic nature of attacks reduced social functions, a situation in which, according to Collier (1999), the population is prevented from using their resources for production activities. In this context, the Koinadugu district experienced frequent interruption of crop cultivation cycles, with insurgencies occurring often mid-season and at harvest time.

The most direct effect of the war on farmers' practices was shown by the complete absence of upland seed materials in the ten villages studied in the Koinadugu district by the time the war ended. Farmers reported that this emanated from the continuous sense of insecurity that had discouraged any form of labour intensive agricultural practice normally associated with upland farming. During attacks on their villages, the survival strategy of the farmers was to create hiding places in the forests where they could stay, and when possible grow some rice in the forest valley bottoms. Upland agriculture was no option because it involved slashing and burning of farm bush as a cultivation practice. The smoke of burning bush would attract mobile units of rebels to the hiding places of farmers. The overall consequence over a long period was the total abolishment of upland farming. This was in part consistent with other reports about Sierra Leone farmers who exhibited the habit of ceasing upland rice cultivation altogether during difficult years (Johnny *et al.*, 1981). From an agricultural biodiversity perspective, such disturbances in upland farming systems created a course for concern because the upland system used to support more diverse crop types than the lowland system (Richards, 1985; Spencer, 1975). Any situation therefore that leads to disturbances in or abandonment of upland agriculture implies negative consequences for genetic diversity and leads to genetic erosion of a large number of crops associated with this type of farming.

4.4.3 Kambia district

By the time the war reached the Kambia district the intensity of fighting had already slowed down, although occurrences of social abuses, violence and the need for food and other necessities by the rebels were still evident. One asset that the rebels found most attractive was the large storage facilities for seed rice. The Rice Research Station on the one hand, and the largest seed production agency, the GTZ Seed Multiplication Company on the other, were both located in the region. Both institutions not only had the largest seeds stores in the country, but were also the direct suppliers of different rice varieties to farmers. The rebels spent weeks looting these facilities and transporting the spoil to their Headquarters. After exhausting the seed stores, the rebels turned their attention to the local producers. Like in the Koinadugu district, continuous insecurity halted farming activities. The difference here, however, was that the farmers were not completely displaced, as in the other districts, and some were able to grow their crops, though under threat from the rebels. This was reflected in the higher number of samples that were collected, compared to the other districts. Also the number of varieties and percentage recovery after one year was higher then for the other two districts.

Although there were apparent differences in the nature by which the war affected the different regions included in this study, some similarities did emerge. For example, in each district, the number of farmers that did not possess seeds immediately after the war was high, giving an indication of large-scale losses of planting materials for rice. It is generally understood that rice farmers in Sierra Leone, like their compatriots in other parts of West Africa, take pride and find security in growing several rice varieties during any one growing season (WARDA, 2003). This culture underscores the very principle of farmers' diversity management (Almekinders and Louwaars, 1999; Bellon, 1997). In the West African region farmers characteristically grow between five and ten rice varieties in any one season. For example, in a survey conducted in Ivory Coast, 1673 seed samples were collected from 306 farmers in 57 villages (WARDA, 2003), indicating an average of six samples per farmer and 29 samples per village. Since farmers would not keep two samples of the same variety, it meant a farmer could keep an average of six different rice varieties. Drawing from these results and those presented in the current research, it can be argued that massive losses or dispersal of rice genetic resources did occur in Sierra Leone as a result of the war. The high number of farmers per village that were without rice varieties supported this conclusion.

Our results do support earlier views of Verpoorten and Berlage (2007) that warfare in developing countries does present severe consequences on plant genetic resources, and that it has negative impacts on agriculture production systems. The most severe impacts include population displacement and deaths of community members, but the loss or dispersal of farmers' seeds is a frequent phenomenon as well. The low number of varieties present in individual villages in our case studied suggests high losses in farmers' seeds per village as well. The low number of varieties in circulation could result in a narrowing of diversity in the long run and a loss of specific genotypes and gene complexes of the rice genome.

Post-war seed recovery forms one of the challenging issues in the reconstruction of the war-ravaged communities. At the end of prolonged wars, farmers returning to their homes often find their seed stocks totally destroyed (Adler, 1995), and the major concern is to rebuild and re-stock the seed infrastructure. The seed materials needed and the additional inputs necessary together define the reconstruction efforts. For example, in the Rwandan civil war, experiences gained from earlier seed relief studies led to the recommendation that in order to address the concerns of post-war diversity losses, it was necessary to give primary attention to the re-establishment of pre-war traditional seed channels. Such channels have the strongest capacity to re-establish local germplasm to rural communities (Sperling, 1996).

In a similar vein, it could be observed that at the end of the war, the Sierra Leone farmer immediately reverted to local seed channels (obtaining seed from relatives, purchasing seeds from the markets, and using a number of seed exchange mechanisms), which they exploited in an attempt to reinstate their seed stocks. This is seed recovery trends similar to those described in Sperling and Cooper (2003), accepting also that seeds sourced from some of these outlets are often of variable quality (Schiedegger and Buruchara, 1991). Whereas seed recovery in the study areas was low directly after the war, variety recovery had become more substantial just one year later. This observation shows that farmers have the ability to replace most of the varieties lost due to war through their local seed systems. In the Kambia district, for example, despite massive looting of the institutional seed stores, the traditional network of pre-war seed exchange offered a strong resilience to the post-war seed system, which, according to the farmers themselves, was vital enough to allow a robust recovery of previous varieties.

Seed rehabilitation through emergency relief agencies, NGOs and government agents was feasible only during the first half of the war, between 1991 and 1995. Seed distribution in war affected areas during this period however turned out to be very ineffective. Even though the agencies used local varieties for distribution, the seeds were bought from local vendors who had little regard for quality and variety purity. Contract farmers who were employed to produce seed conducted seed multiplication on the basis of cash incentives, i.e. favouring seed quantity against quality. Another complicating factor was that insurgent activities became more frequent during the harvest season, leading the contracted farmers to sometimes harvest their crops before physiological seed maturity had occurred. The seeds produced were hence often of poor quality and could not meet farmer requirements. In addition to these problems, the seeds were often distributed without consulting the farmers, which often resulted in arrival of seeds too late for the growing ecosystem. As a consequence, farmers often ended up using seed supplies as food (Conteh, 2004). These kinds of problems have been reported before, and are often associated with seed relief agencies after disasters (Sperling and Cooper, 2003).

4.5 Conclusions

Our investigations revealed that the farmers, their seed systems and seed stock were severely affected as a consequence of the war, and so also was the entire farming systems. In the three districts studied farmers were affected in different ways, which led to different patterns of loss of rice seed resources. The extent of seed losses was variable as a number of varieties were actually dispersed in the region, instead of being totally lost. There was evidence that a number of the varieties reported lost could be recovered by the farmers after the war. However, when compared to the number of rice varieties that traditional farmers in West Africa are known to grow (and possess) on their farms, we can conclude that a drastic loss of rice genetic resources in Sierra Leone occurred as a result of the war.

Farmers demonstrated the desire to retrieve their lost materials and they did so with different levels of success through using the regular channels of their local seed systems. This indicates that for post-war seed restoration efforts, either undertaken by NGOs or government agencies, there is a need to adjust all levels of support to functional farmers’ traditional seed systems and seed recovery processes before bringing in relief. Seed rehabilitation assessments should incorporate both knowledge of the manner in which the war was conducted, its impact on the farmer community, and of farmers' seed systems in the pre-war situation. Such systems might be vital in post-war efforts towards seed recovery.

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Chapter 5

Rice varieties in post war Sierra Leone

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Abstract

Rice has been grown in Sierra Leone for subsistence purposes for more than a thousand years using traditional landraces and introduced modern cultivars. Sierra Leone falls within the West African belt where one of the cultivated species of rice, *Oryza glaberrima* is domesticated. In addition to *O. glaberrima*, a large gene pool of Asian rice, *O. sativa* that was introduced into the country between the 15th and 17th centuries occurs. Over a recent period of almost 20 years, this rich genetic resource pool was threatened by war, and fears of genetic erosion in the rice germplasm prompted this research. Our findings revealed that though there were huge losses of rice varieties reported by farmers as a result of the war, a good number of the varieties prevalent before the war had been recovered within one year after the war by the farmers themselves. The high survival rates of many varieties by the end of the war were attributed to factors including 1) the extent of pre-war dispersal of the variety, 2) the phenomenon of phenotypic plasticity, and 3) varieties existing in multiple subsets. This knowledge is a vital clue to plant breeders for breeding varieties suitable for disaster-prone regions of poor communities.

Key words: varieties, rice, *Oryza*, war, upland, lowland, ecosystem, genetic resources, Sierra Leone.

5.1 Introduction

The genetic resources of cultivated crops and their wild relatives form a most useful and economically valuable part of our planet's biodiversity. All over the tropics subsistence farmers use traditional landraces as key elements of their livelihood, and over time farmers have therefore developed various strategies to maintain them. Furthermore, these varieties have formed and continue to be the raw materials for plant breeders in the development of modern varieties, in particular in developing countries (Lenne *et al.*, 1997). Until today, rice cultivation in Sierra Leone depends on subsistence farming that involves the use and maintenance of both traditional landraces and modern cultivars, which collectively form farmers' varieties (Due and Karr, 1973).

By geographic location, Sierra Leone falls in the center of the West African rice zone which extends from Senegal to Ivory Coast (Due and Karr, 1973; Simons, 1986), and the country forms part of the region of domestication of African rice *(O. glaberrima* Steud.*)* (Due and Karr, 1973; Linares, 2002). This explains the long history of genetic improvement and conservation of rice in the country, which is the national staple crop. As part of this history, the West African Rice Station, later called the Rice Research Station (RRS), was established in 1934 to conduct research on rice. Between 1934 and 1953, the Station introduced 312 rice varieties from 27 countries that represented major rice growing regions in the world. Of these varieties, 190 were included into breeding programs, while others were simply introduced through multi-location field trials, selection and multiplication on farmers' fields. To this date, some names of these introduced varieties do appear among the varieties grown by farmers (GOSL, 1953; Richards, 1986).

Rice is cultivated within two major production ecosystems, namely the upland and lowland ecosystems, which are characterized by unique ecological conditions (Dries, 1991; Kline, 1956). The upland ecosystem consists of plateaus, hills and slopes that depend on seasonal rainfall for water supply, and accounts for about 75% of total rice production. The lowland ecosystems include coastal mangrove swamps, inland valley swamps, riverine grass lands, and grassy flood plains (Kline, 1956). Specific rice varieties resulting from farmer selection are cultivated in each of these two rice production systems, the involved varieties being recognized by certain morphological traits. In addition to these traits, the varieties are further classified by farmers on the basis of their growth duration (short duration (90 – 110 days), medium duration (110 – 120 days) and long duration (more than 120 days)), according to the number of days the varieties have to be grown in the field from sowing to harvest (RRS, 1989).

Research efforts at the RRS continued in the 1960s and 1970s with the introduction of rice germplasm from the International Rice Research Institute (IRRI) in the Philippines, the International Institute for Tropical Agriculture (IITA) in Nigeria and the West Africa Rice Development Association (WARDA), with headquarters then in Liberia, but nowadays in Benin. In the 1980s, WARDA developed joined research efforts through a substation in Sierra Leone with special emphasis on the development of varieties suitable for mangrove and associated mangrove ecosystems. For its breeding programs, WARDA introduced a number of exotic modern cultivars in the country (WARDA, 1993). Varieties developed through research and breeding was made available to farmers via various seed dissemination mechanisms. In addition, farmers themselves were known to conduct selection amongst traditional landraces, thereby contributing to the continuous improvement of their rice varieties (Longley and Richards, 1993; Richards, 1986).

Notwithstanding the rich history of rice in Sierra Leone, farmers have recently been facing severe losses of germplasm caused by various factors, including the loss of agricultural ecosystems (Squire, 2001). Since the country experienced a 10-year long war, this may have further affected the state of crop genetic diversity in the country, especially the diversity of the rice crop (Monde and Richards, 1994). The conflict resulted in a massive displacement of farmer communities, and as a result the entire crop production sector was crippled (Jalloh, 2006; M'Bayo, 2006; Schafer, 2006). Such a disruption of traditional agricultural systems has the potential to destroy indigenous seed systems that in turn could jeopardize the future of traditional agriculture in the country.

The current research was designed to assess the effects of war on rice genetic resources in Sierra Leone. Loss, displacement and recovery of varieties were studied. In the process, different elements of variety recovery, i.e. availability, accessibility and acquisition were distinguished.

5.2 Materials and methods

Field expeditions were conducted between December 2003 and February 2004 by a team consisting of collectors and security personnel, as well as interpreters and other support staff. The expeditions targeted three districts, i.e. Kono, Koinadugu and Kambia in the east, north and northwest of the country respectively. These districts had been selected based on the available prior knowledge, their accessibility and security issues. Also taken into consideration was the fact that the war had affected these regions in different time periods and in different ways. In each of the districts, 10 villages were selected based on differences in ecosystems between them. For complete details of the methods employed for obtaining data and seed samples, see chapter 3.

5.3 Results

A total of 280 rice samples comprising 119 different varieties (based on farmers' classification) were collected from 30 villages. Of these, 48 varieties were obtained more than once from different farmers, ranging between two and 16 times, and eight varieties were collected in more than one district (Table 5.1). Three varieties *Yaka*, 'Rok 3' *and* 'Rok 5' were collected in all three districts while *Buttercup, Chinese, Pa muslim, Rodin china,* and 'Rok 4' were obtained in two of the three districts. Other varieties that occurred in higher numbers (8 samples and above per district) were *Mamykuwa, Yabassi* and *Gbeapui* in the Kono district, *Marobia* and *Yaraduka* in the Koinadugu district and *Pa taim* in the Kambia district. The largest number of samples (118) was collected from the Kambia district, followed by the Kono (102 samples) and Koinadugu districts (60 samples). No less than 71 varieties (60%) occurred only once in the total sample set, the largest number occurring in Kambia (41 varieties), whereas in Koinadugu 17 and Kono 13 unique varieties were obtained.

Table 5.1: Rice varieties occurring more than 2 times giving districts of collection, number of accessions and ecosystem.

Variety name	District	No. of accessions	Ecology
Bai sama	Kambia	3	Lowland
Bako yawa	Kono	3	Upland
Beyaya	Koinadugu	3	Lowland
Buttercup	Kono, Kambia	9	Lowland
Chewulay	Koinadugu	2	Lowland
Chinese	Koinadugu, Kambia	2	Lowland
Donsobofeo	Kono	6	Lowland
Fullahyongoe	Kono	3	Lowland
Gbassnyin	Kambia	5	Lowland
Gbeapui	Kono	11	Upland
Gborokundeh	Kono	3	Upland
Gbrunumpa	Kambia	2	Lowland
Jangai	Kono	2	Upland
Kojogbuafehun	Kono	3	Upland
Kwatik kundor	Kono	4	Lowland
Mamy kuwa	Kono	10	Upland/Lowland
Marobia	Koinadugu	8	Upland/Lowland
Nerika	Koinadugu	2	Lowland
Njewulay	Kono	4	Lowland
Pa 3 month	Kambia	5	Upland/lowland
Pa bop	Kambia	2	Lowland
Pa bunch	Kambia	3	Lowland
Pa kamara	Kambia	2	Lowland
Pa kolma	Kambia	6	Upland/Lowland
Pa mayeni	Kambia	2	Lowland
Pa mer	Kambia	2	Lowland
Pa muslimi	Kono, Kambia	6	Lowland
Pa saliforeh	Kambia	2	Upland
Pa taim	Kambia	12	Upland/Lowland
Pa teden	Kambia	2	Lowland
Pa yan gbassay	Kambia	4	Lowland
Pa yenet	Kambia	3	Lowland
Packet rice	Kono	2	Lowland
Rodin china	Koinadugu, Kambia	4	Lowland
Rok 10	Kambia	2	Lowland
Rok 3	Kono, Koinadugu, Kambia	6	Upland
Rok 4	Kono, Koinadugu	2	Upland/lowland
Rok 5	Kono, Koinadugu, Kambia	3	Upland/lowland
Sandimbae	Kono	8	Lowland
Sinuwa	Koinadugu	2	Lowland
Soronkadi	Koinadugu	6	Lowland
Weeh	Kono	2	Lowland
Wuseh	Koinadugu	2	Lowland
Wusii	Kono	4	Lowland
Yabassi	Kono	10	Upland
Yaka	Kono, Koinadugu, Kambia	16	Upland/lowland
Yaraduka	Koinadugu	9	Upland/Lowland
Yonjorwa	Kono	6	Lowland

Based on the ecosystem where the varieties were grown, the highest number of samples consisted of lowland varieties (see Figure 5.1).

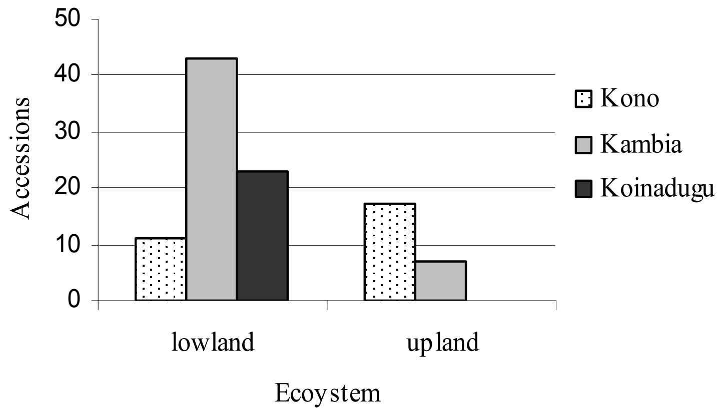

Figure 5.1: Rice accessions collected in three districts, divided by ecosystem.

All samples obtained in Koinadugu district were reported to be lowland varieties, but according to respondents, farmers used to grow a number of these varieties in the upland ecosystems before the war, which apparently they had adapted to the lowlands. In Kambia, 86% of all varieties were described as lowland ecotypes, while in the Kono district only 39% were described for that category. The remaining varieties were upland ecotypes, the most prominent in the Kambia district being *Pa 3 month* and 'Rok 3', in Kono District *Gbeapui,* and *Yabassi*. Four of the varieties, *Yaka, Pa 3 month,* 'Rok 4' and 'Rok 5' were reported to be adapted to both the lowland and upland ecosystems. With respect to the growth duration of the varieties, our results revealed that a majority of the varieties fitted a three-month growing period, and the number of varieties decreased as the growth duration increased (Table 5.2).

Table 5.2: Growth duration of varieties successfully recovered by farmers.

Duration	**Accessions**		**Varieties**	
	Total	%	Total	%
3 months	132	46	48	39
4 months	83	29	42	34
5 months	52	18	17	15
6 months	11	4	8	7
7 months	3	1	2	2
	281		117	

The number of varieties reported as lost as a direct consequence of the war for all three districts was 302, although we were led to believe from interviews that 49 varieties of these losses reported occurred in periods preceding the war. Figure 5.2 explains the proportion of varieties that were collected and those that were reported lost as a consequence of the war.

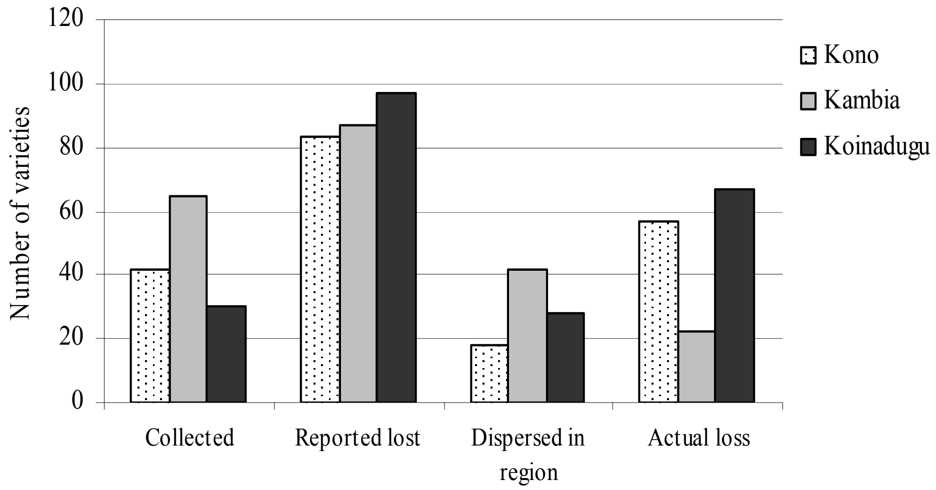

Figure 5.2: Presence and loss of post war rice varieties in Sierra Leone

The lost variety category was subdivided into those dispersed in the region and those that were regarded completely lost and could not be found anywhere in the study areas. In the Kono district a variety that was reported lost most often was *Bako*, followed by *Ndwiwa* and *Yaefini*. Also in Koinadugu district *Bako* was the variety that was reported lost by the largest number of farmers, followed by *Pa DC* and *Fosa*. In the Kambia district, *Pa damba* was the variety that was most commonly reported lost. An overview of varieties that were lost in each district is given in Table 5.3. A high number of them appeared to belong to a category characterized by long growth duration, for example, the *Bako* varieties in both the Kono and Koinadugu districts, and *Pa damba* in the Kambia district.

Table 5.3: List of varieties that were actually lost per District.

Kono (58 varieties)	Angbon, Bako, Fambecheakor, Gbakidu, Gbondobai, Gborukusi, Gbuyumbui, IDA rice, Jangai, Jewule, Joewanjae, Jumukui, Kamaboe, Kenketeh, Korgbandi, Korkoe, Kpendeke, Liberia, Manawa, Manikaie, Manjolee, Mbogotui, Monegbou, Mornjoye, Nbowa, Ndwiwa, Ngofee, Ngoyomboi, Ningiboe, Njewule, Nsoma, Pa gbassay, Pa loi, Pa rap, Pa remeh, Pa temne, Pa yenet, Packet rice, Pendeke, Peniwiki, Pini pini, Sanguama, Tormoi, Tunfukoe, Wokorun, Yaefini, Fengbe, Bafinkoe, Bagbefine, Kinigbe, Yolikoi, Nimimifine, Chefene, Niewa, Bumamusu, Bendeyaseh, Yiefa, Sewabefe.
Kambia (21 varieties)	Amadu fenkre, Angborumpa, Chinese, Gbakaishan, Gbalkanta, Kalisaidu, Kebedeh, Koinkini, Pa bai Feth, Pa barakamadina, Pa bisgbonko, Pa blackmampa, Pa blue stick, Pa chief caulker, Pa damba, Pa espected, Pa gbonkor, Pa gbut, Pa kiamp, Pa lead.
Koinadugu (63 varieties)	24, Adulaiya, Alietorma, Bafaaka, Bako gbe, Bako yawa (Bakowule), Bameti, Basonka, Bataba, Bawaiko, Benserna, Bondeyaka, Borkuma, Boronkolo, Bubuyama, Fosa gbe, Fosa wule, Friwa, Gbakadu, Gbansima, Gbolokolo, Gbondoba, Gboromayaka, Gewonku, Isoma, Junkun, Kauronka, Kebede, Kobawule, Koneche, Korikori, Kpanyale, Kundufin, Kungomusa, Kurikuri, Ledder, Limba, Memerayaka, Nsorma, Padissi (Pa D.C.), Panya, Rodinchina, Sakalie, Seduya, Segbama, Sorgbete, Sulgboteh, Tantifo, Three (3), Waillor, Wolekore, Yan, Yaya, Kinikoe, Nfa, Nnamusu, Munanfa, Njewulefin, Pa karifala, Kai kai, Sumbarakini, Njewulegbe, Morkore.

During data collecting missions, it became obvious that a number of the varieties that were lost in a given village as a consequence of the war might soon be recovered because farmers were already aware that these varieties still occurred elsewhere. As a matter of fact, variety recovery had been an on-going activity by the farmers, also during the war years, and in the process new varieties were obtained whenever possible. The general consensus in all three districts was that farmers relied mostly on relatives, friends and neighbours in order to obtain rice varieties, sometimes as gifts, but mostly through traditional exchange systems. Farmer to farmer seed gifts, and the exchange of varieties is part of the traditional seed systems that operates under well defined conditions (Almekinders *et al.*, 1994; Green, 1987). Most of the varieties farmers wished to recover were those with short growth duration, in direct contrast to their attitudes regarding lost varieties with long growth duration. The most requested varieties in the Kono district were *Yaka, Yabasi* and *Mamay kuwa,* which were prominent in their seed collections before the war. In the Koinadugu district, the most requested varieties were *Yaraduka, Sinuwa and Soronkadi. Pa taim, Buttercup, Pa muslim* and *Pa kolma* happened to be the varieties that were mostly sought for in the Kambia district. Some new varieties obtained in Kambia turned up from unlikely sources: two reported to have been picked from the roadside, one from a floating raft and three off-types from neighbours' farms. Off-types on cultivated rice farms are occasional rice plants that are different from the variety planted (Tin *et al.*, 2001). The three off-type varieties in our sample were picked by the farmers and grown separately, and they expected to keep them if they continued to meet their variety requirements. The list of selected varieties that were recovered and prominent again among farmers, together with the sources from which they were obtained is given in Table 5.4.

Table 5.4: Sources of recovery and general characteristics of retrieved rice varieties.

Variety name	**Source**	**Remarks**
Bai sama	Wala, bought from the market, kin	
Bako yawa	Kochero, Sando	Obtained after war
Beyaya (Jaya)	Family member	
Buttercup	Mano, Mende land, Pitfu, Sentai - Temne land	Short seeds, awnless; short duration; obtained during war
Chewulay	Family member, madina	Obtained for 2 years now; exchange with Marobia (another variety)
Donsobofeo	Majendu, Mende land, Mnsundu, Boliya	Sweet aroma, Obtained during and after war
Fullahyongoe	Bendu, Sando	Obtained during war
Gbassnyin	Rokubop, Masiri of Dubia, picked from rafter by friend	Exchanged with another variety
Gbeapui	Sumaru Mende, Majendu Mende, Mansundu Mende	Obtained after war, fee for work
Gborokundeh	Boliya Koranko land, Fomaya Mende,	
Gbrunumpa	Wala, bought from the market, kin	Maintained during the war for 3 years
Jangai	Majendu, Mende land, Mnsundu, Boliya	Obtained only the year before
Kojogbeafehun	Majendu, Sumaru - Mende land, Kangama Gorama	Sweet cooking aroma, Swells when cooking; exchange oil for seed after war
Kongoma yaka	Punduru, Gorama, Kamban	Can be grown in both Upland and lowland
Kwatik kundor	Wala, bought from market	High yielding
Mamy kuwa	Mende land, Sando, Kenema Ngolama	Tillers profusely; obtained during war
Marobia (Rok 24*)	Fadugu	Kept the variety in hiding durign war
Njewulay	Mende land	
Pa 3 month	Kale, Kono	Obtained last year
Pa bop	Off-type from Dibia	Obtained last year
Pa bundu	From father, from mother	Maintained for the past five years
Pa kamara	Rokupr, Makatik, Wala	Obtained last year
Pa kolma	Rouged from farm, Wala, Kutolon - Meni curve	Obtained last year
Pa mer	Off-type, picked from neighbours farm	Maintained now for 3 years
Pa muslimi	Koneke, - Temne land, Wala	High yielding
Pa taim	Kamba, Wala, Mapolo, Gbonkomaria	Maintained for two years now
Pa teden	Rotain, Wala	Maintainde now for 3 years
Pa yan gbassay	Wala	Exchanged with another variety
Pa yenet	Limba land	Maintained for five years now
Rodin china	Kompala, Sengbe C/dom	Hid seed in cave for 2 years during war
Rok 4	Bought from the market	Obtained last year
Rok 5 (india)	Farmer organization	Maintained now for 2 years
Sandimbae	Punduru, Mende land, Bunambu	Obtained after war
Soronkadi	Yelunka land, Senkuya	Obtained only a year ago
Weeh	Bought from the market	Long durartion; high yielding
Wuseh	Tongo, mende land,	Obtained in displaced camp, kept for 5 years
Wusii	Kenema Ngolema, Peya, Sewafe	Obtained during war, oil for rice
Yabassi	Majendu, Fendehun, Punduru, Sumbaru, Golama,	Onion aroma when cooking, Exchanged palm oil for seed, fee for labour
Yaraduka	Mamuduya, Gbeninkoro, Bendukoro - Koranko	Sought after the war
Yonjorwa	Ngorama - Kono, Tama forest, Punduru	High yielding and tillers well.

In addition to farmers' seed channels that accounted for the varieties that were recovered, NGO interventions were undertaken in the form of seed rehabilitation in relatively secure regions of the Kono and Koinadugu districts. These interventions were possible under relatively calm circumstances because all NGO activities stopped for most of the time when their convoys came under attack. In the Kono district, the NGO that was most active was World Vision while in Koinadugu district, a number of NGOs including the International Development Agency (IDA), the Christian Relief Services (CRS), National Commission for Social Action (NACSA), and the Christian Church Foundation (CCF) were active in distributing seeds to farmers. At the time of our visits, no NGO activity was reported in the Kambia District, but a number of them had been active during the course of the war, i.e. before the district was engulfed with fighting in 1995. The three most prominent of these, better known as Community Based Organizations (CBOs) were the Kanfoka Farmers Association (KAFA), the Farmers Seed Association (FSA) and the Christian Farmers Association and Development Agency (CFADA). Both the NGOs and CBOs, including those in the Kono and Koinadugu districts, received funding from the World Bank, the European Union, the UK Department for International Development (DFID), and the United Nation's High Commission for Refugees (HCR) in order to purchase local varieties from 'seed secure' farmers and to distribute them as planting materials to other farmers. In 2003, for example, the Ministry of Agriculture reported that NGOs were responsible for distributing 3,912 metric tonnes of rice seeds to farmers, nationwide, with a third of this believed to have been distributed in the present study region (MOA, 2004). Actual variety names were not included in any of the government or NGO/CBO reports, but it was generally believed that local genetic resources were used, and a good number of farmers were paid on contract basis in order to multiply seeds that were later distributed (Sulaiman, 1993).

5.4 Discussion

The seven varieties that occurred in more than one district had obviously been distributed across the regions. They belong to different variety groups. *Buttercup* and *Chinese* both are varieties that are known to have been selected from commercial rice imported from China. Milled rice is imported from China as grain for food, but occasionally, husked seeds are found in the grains. Farmers have successfully developed varieties from those seeds, giving them names such as *Chinese*, or *Buttercup* (the cup that traders used to measure Chinese rice in the market). In contrast, 'Rok 3', 'Rok 4' and 'Rok 5' are products of plant breeding programs at the Rice Research Station (RRS) in Rokupr. The Station developed up to 30 varieties (the Rok-series) over its more than 60-years of existence. Although adoption rates for most of those varieties had been low pre-war (Adesina and Zinnah, 1992), some did find their way into farmers' seed systems. The three Rok varieties recovered in this research represent such previously adopted varieties, especially in the Kambia and Koinadugu districts. The fact that they were present in more that one location after the war demonstrates their success with farmers. *Yaka* and *Pa muslim* are traditional landraces that have been known to be very popular with farmers.

Variety dispersal across rice farming systems in Sierra Leone as discussed above is possible only through farmers' seed distribution channels as these existed before the war. Commercial or formal public seed systems have not been well developed in the country, even before the war. The farmer seed channels involves farmer-to-farmer exchange mechanisms mostly based on traditional social networks and family relations that have been found useful for the diffusion of varieties (Almekinders *et al.*, 1994; Cromwell, 1996; Maredia and Howard, 1998). Pre-war records indicated that Sierra Leone farmers obtained up to 80% of their rice varieties by this informal exchange system (Jusu, 2000). The current study has also revealed that under war and post-war conditions farmers were able to obtain seeds from various sources through these same informal systems, and wartime exchanges of seeds were sustained because not every region in the country was engulfed in fighting at the same time (see chapter 4). Farmers were capable of mapping out secure regions where they sought refuge, or where they moved to in search of planting materials when their own towns had fallen victim to insurgent attacks. The same principle allowed post-war farmer seed rehabilitation processes because farmers were able to trace their varieties to known sources and familiar terrain when security returned to their regions.

The *Yaka* variety presented a unique case in which certain characteristics outlined by farmers may have enabled it to survive the war in large number and became widely distributed. Firstly, the fact that the variety existed in all three districts and in many villages demonstrates its widespread acceptance by farmers. Secondly, the variety has the potential to grow in both upland and lowland ecosystems, which demonstrates phenotypic plasticity. This characteristic appeared invaluable during the war, especially in the Koinadugu district where farmers claimed to have "re-adapted" most of their upland varieties to the lowland ecosystem. Some of the forest lowlands were not as optimal for rice cultivation as the farmers were used to, and many ecological challenges appeared, to which *Yaka* adapted well. According to the farmers, during the periods of increased insecurity in the district, upland farming could no longer be practiced because it involved bush brushing and burning practices in order to clear the land. This was not only labour intensive, but the smoke of burning bush could reveal the hiding places of displaced farmers to roaming rebel groups, which made them vulnerable to attacks. Because of this, lowland agriculture that could be conducted more secretly was the only option for rice production. Although other varieties were grown, *Yaka* proved very successful and provided sustainable yields under repeated cultivation circles. The third characteristic of *Yaka* relates to a property the farmers believed has helped the variety to succeed in difficult circumstances, i.e. that it existed in multiple forms. As understood by the farmers, this ability enabled the different genotypes of the variety to adapt independently and within a short time to marginal niches in rice fields. This finding tends to agree with Richards (1986), who also encountered several *Yaka* varieties in the southern districts of Sierra Leone, a region characterised by different cultures and separated by several hundred kilometres from the present study area. The *Yaka* varieties constituted 15% of all rice planted in that region, including 'floating' (flood tolerant), lowland and upland types. They were collectively referred to as *Yaka* rices and broadly characterized in two forms, namely *Wonde yaka* and *Ngiyema yaka*. One of the RRS released varieties, 'Rok 3', which happened to be present in all three districts in the current study is a local selection of *Ngiyema yaka* (Richards, 1986).

The exact origin of the initial *Yaka* variety is uncertain and the name itself carries little meaning except when preceded by a descriptive word based on the ecology in which the particular variant is grown. In the Kono district, the variety is known either as *Kongoma Yaka* and *Gbendema Yaka* for upland and lowland eco-types respectively. Similarly, in the Koinadugu district they are referred to as *Gbelema yaka* and *Korba yaka* for upland and lowland *Yakas* respectively.

The *Yaka* variety can therefore be regarded to represent and symbolize the other varieties that survived the war in multiple locations and with many farmers, as it seemed to embody useful characteristics that made this possible. It is likely that the three characteristics described for this variety do exist in other rice types, though not all at once, for example, 'Rok 3', 'Rok 4', and 'Rok 5', *Chinese* and *Buttercup* occurred in more than one district; *Gbeapui, Mamykuwa, Pataim* and many other varieties appeared in many villages within the same district; and *Njewule, Pa3 months* and *Pa yangbessay* have the potential to grow in both the upland and lowland agro ecologies. These attributes not only enabled most of the varieties to survive the rigors of the war in large numbers, but also allowed the farmers' seed systems to remain effective during the long periods of insecurity.

The relatively high number of lowland varieties collected in this study suggests an increase in lowland rice farming system in at least two of the three districts studied. A number of records suggest that upland rice cultivation predominated throughout Sierra Leone until as late as the 1980s, but this seems to have changed more recently (FAO, 2000). The Kambia district is home to the Rice Research Station and also possesses one of the vast stretches of mangrove swamps in the country. Mangrove rice cultivation has therefore been on the increase in this region partly because of new lowland water management technologies developed at the Station, which in turn led to the expansion of rice cultivation in this eco-system (MOA, 2004). Research conducted in this district in 1996 revealed that there were more varieties for the lowland agro-system than for the upland (Jusu, 2000). It is also well documented that the yield potential of mangrove rice is much higher than for the other traditional rice ecosystems (Agyen-Sampong *et al.*, 1988; Agyen-Sampong *et al.*, 1991; Fomba, 1994). For the Koinadugu district on the other hand, inland valley swamps do exist and lowland varieties appeared to have increased because farmers had abandoned all of their upland varieties for reasons directly associated with the war (see chapter 4). Farmers in this district also reported that they had relocated some of their upland varieties to the lowlands.

Only the Kono district appeared to have more varieties for the upland ecosystem than for the lowland, partly because unlike the Kambia and Koinadugu districts most of the varieties now grown in the Kono district were obtained from another district in the East and South of the country. This occurred since the Kono farmers were completely displaced for long periods during the heat of the war and were in another district where they sought refuge and rendered farm services to their hosts. The varieties they received were gifts from their hosts and a fee for farm services rendered and these were mostly upland varieties. Apparently, the hosts kept the lowland varieties for themselves. Upon return to their regions after the war, Kono farmers sought varieties from neighbouring districts from where they obtained both lowland and upland so that they could broaden their collections.

Rice variety recovery formed a major activity in the immediate post-war situation, and it appears that farmers were very selective in the varieties they were looking for. At the time of our visit, farmers were just recovering from disaster and their demand for seed was very constrained by lack of financial capital. They therefore increasingly sought to access seed from a range of other sources than the market, in particular from other farmers whether living close by or in distant regions. A similar situation for farmers recovering from disaster in Rwanda has been reported by Remington et al. (2002). In Sierra Leone, data covering the periods during the war show that farmers were still able to maintain their seed channels (Longley, 1997). For example, farmers in the Kambia district focused on recovering the varieties they cultivated before the war by relying on their relatives, friends and neighbours, and a similar trend was observed in the Koinadugu district. Finally, in the Kono district, farmers could only recover a few of their former varieties, such that much of the varieties they possessed post-war were obtained from regions outside their own. The Kono farmers reportedly made long journeys in search of some specific varieties that they knew of before the war. Thus, farmers in this district came to rely on additional varieties obtained from distant external sources, a pattern that is in agreement with Tripp's (2000) finding that off-farm and external seed sourcing does play a role in seed recovery after disasters. In this situation, farmers took the challenge to try out new varieties in order to restock their rice genetic resources.

In the variety recovery process, one class of varieties that the farmers did not show much interest in were those with very long growth duration simply because of immediate food security needs. Short duration varieties, such as *Yabassi* and *Mamy kuwa* in the Kono district; *Yaraduka, Sinuwa and Soronkadi* in Koinadugu and *Pa muslim* and *Pa kolma* in the Kambia district were especially favoured during the post-war situation as a risk limiting strategy. These varieties and a number of other short duration types were already popular before the war as a cultivation strategy for alleviating hunger caused then by seasonal food shortages (Richards, 1986).

5.5 Conclusion

It was inevitable that as a consequence of war on-farm genetic resources were lost, signifying genetic erosion. In Sierra Leone this happened in different stages, and in different forms. The circumstances that led to the loss of varieties in the three study regions were explained by the manner in which the war affected the farmers. This chapter has demonstrated that the varieties that survived the war in large numbers were those that had wide pre-war dispersal, whereas some had the ability to grow in both agro-ecosystems. In our example the *Yaka* variety was a typical representative of such a variety, offering a survival mechanism during the entire period of the war. It is clear that more varieties might have been saved if they possessed traits as described for the *Yaka* variety. This could form an interesting finding for plant breeders who could include genetic characteristics that exhibit phenotypic plasticity and resilience (especially multiple adaptive capacities) into new varieties in order to reduce the chances of genetic erosion under stress conditions in the future.

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Chapter 6

Phenotypic diversity of Rice in post-war Sierra Leone

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Abstract

Morphological traits were studied to investigate phenotypic variation in rice varieties obtained in the early post-war period in Sierra Leone. In total 280 samples of both upland and lowland rice varieties belonging to the species *O. glaberrima* and *O. sativa* obtained from farmers in three districts were studied. Descriptive statistics showed significant differences for traits between districts, but higher differences were expressed for more traits between the two agro-ecosystems. Quantitative and qualitative data gave similar results with redundancy analysis for distinguishing between upland and lowland varieties. The quantitative traits that were most distinctive in describing variation were time to 50% flowering, number of days to maturity, the number of tillers and number of productive tillers. Regarding qualitative data, the most discriminatory traits were flag leaf angle, panicle exertion, seed coat pubescence and bran colour. A biplot for both datasets also gave strong discrimination between the two ecosystems and the districts. The dendrogram based on the qualitative and quantitative data showed clusters of varieties on a regional basis on the one hand, and on the other on the basis of the species to which the varieties belonged. One variety, *Pa three months*, suspected of being a spontaneous hybrid between the two rice species, clustered closely with *O. glaberrima*.

Keywords: morphological traits, phenotypic variation, ecosystem, rice, Sierra Leone

6.1 Introduction

Rice is the most important food crop in Sierra Leone. Its cultivation is estimated to cover 400, 000 ha, and an average of 630,000 tons of grain per year was produced in the 1980s (MAFF/FAO, 1992). Countrywide, production ecosystems are classified as either upland or lowland, depending on their natural water supply, and farmers naturally classify their rice varieties according to the ecosystems in which they are grown. Upland rice farming, which is characterized by rain-fed conditions, has been practiced in Sierra Leone for over 300 years, and to this day accounts for 60% of the national rice production (KIADP, 1997; RRS, 1976). The lowland system is subdivided into five agro-systems: 1) mangrove swamp proper, 2) associated mangrove swamps, 3) inland valley swamps (IVS), 4) bolilands and 5) riverine grasslands, all of which are characterized by different water regimes and soil conditions (Smaling *et al.*, 1985; UNDP, 1992). Although traditional rice production still take place predominantly in the uplands, recent figures show a steady increase in the share of lowland ecosystem production since the late 1970s (KIADP, 1995).

The two cultivated rice species, *Oryza glaberrima* Steud. and *Oryza. sativa* L., are both grown in Sierra Leone by traditional farmers. *O. glaberrima,* widely known as African rice, is believed to have been domesticated in West Africa (Bezançon and Diallo, 2006.; Havinden, 1970; Oka, 1988), and is endemic to the region. *O. sativa* is known to have originated in Asia (Khush, 1997; Meertens, 2006), and was introduced into West Africa through historic trade routes. Some *O. sativa* varieties have been present in the region for more than a hundred years so that farmers confidently classify them as endemic and group them with their traditional varieties (Jusu, 2000).

Historic records show that since the 1930s more than 300 rice varieties (mostly *O. sativa*) were introduced through formal channels into Sierra Leone from different countries around the world (GOSL, 1953). Some of these introduced varieties have survived within traditional production systems to this date. Other sources of *O. sativa* varieties include cross-border farmer-to-farmer exchange with neighbouring Guinea, farmer selection from imported rice grains and germplasm originating from the research programs at the National Rice Research Station at Rokupr (RRS) (Jusu, 2000). More recent introductions have been brought into the country through collaborative efforts between the RRS and the centres of the Consultative Group on International Agricultural Research (CGIAR), in particular the West Africa Rice Development Association (WARDA), the International Rice Research Institute (IRRI) through the International Network on Genetic Evaluation in Rice (INGER-Africa), and the International Institute for Tropical Agriculture (IITA) (MAFF/FAO, 1992; WARDA, 2000).

With this background, Sierra Leone is renowned for its strong genetic resource base for rice because of the concomitant presence of numerous landraces on the one hand, and of genotypes of exotic origin on the other (ACRE, 1986). Foreign genotypes that were adopted by farmers and introduced into the farming systems were grown together with local landraces and these were maintained in addition to new cultivars developed at RRS. Taken together, this contributed to the success and stability of the rice crop in often very harsh and generally underdeveloped environments in the country.

The production systems for rice were developed within the framework of a dynamic on-farm conservation system that was based upon farmers' knowledge and robust traditional seed supply channels. These channels (known as farmers' seed systems, or informal seed systems) involved locally organized seed production and dissemination mechanisms whereby farmers obtained seed directly from their own harvest, through barter among friends, neighbours and relatives, and from local grain markets or traders. Not only in Sierra Leone, but worldwide, the traditional seed system provides between 80% and 90% of the farmers' seed needs (McGuire, 2001). Technical knowledge and traditional agricultural standards such as variety exchange amongst farmers contribute strongly to seed system performance, which allows different functional channels, e.g. seed purchase to respond to locally determined preferences. In addition, existing knowledge systems have resulted in consistency in the naming of varieties, which in itself gives helpful clues to the extent of phenotypic and so also genetic diversity at the farm level.

However, over the last decades, accelerated loss of plant genetic resources has been reported throughout the country (Davies, 1987; Lowes, 1970) which has caused concerns in the agricultural and food production sector. Important among the threats to rice resources are changes in cultivation patterns, increase of rural – urban migration, poverty, loss of agro-ecosystems through timber harvesting, and the frequency of soil erosion and wildfires. In addition to these, the most recent and devastating cause of genetic erosion has been the civil war that lasted for more than one decade (1991-2003). It disrupted agricultural activities in the entire country and crippled virtually all production systems, including farm-level infrastructure. This has led to a currently very limited knowledge on the status of rice genetic resources in the country. Until 2004, when the present research was started, seed supply (whether in the form of foreign introductions, research products, farmer exchange or trading routes) was largely blocked, while at the same time the above mentioned factors leading to loss of genetic materials kept playing an increasing role (Squire, 2001). In this context, the lack of exact information about the surviving rice genetic resources nationwide was disturbing. Such information would be useful for the direction and rationalization of genetic resource conservation, but more importantly also for restoration attempts in areas where genetic erosion had occurred. The objective of this research therefore was to investigate the status of rice genetic resources in post-war Sierra Leone, so that the results can be used to formulate sustainable management options and conservation strategies.

6.2 Materials and Methods

6.2.1 Study sites and sample collecting

The study regions covered three districts, Kono in the east, Koinadugu in the north and Kambia in the northwest of Sierra Leone. A field expedition was conducted covering 10 selected villages in each of the three districts in December 2003 and January 2004, immediately after the end of the civil war, in order to collect seed samples of farmers' rice varieties available at the time of our visit. During the visits to the villages, we invited the farmers to bring all the rice varieties they had in their possession, both the ones grown in the previous year and those they had recently acquired. For details on the field expedition for obtaining rice samples and the associated passport data, see chapter 3.

6.2.2 Field nurseries

For the purpose of this study we have grouped all agricultural lowland (or hydromorphic) subsystems, i.e. the mangrove swamps, inland valley swamps, the bolilands and the riverine grasslands in Sierra Leone under the name lowland agro-ecosystem, and all rain fed uplands, including upland ecological niches under upland agro-ecosystem. Varieties that adapt to either the lowland or the upland agro-ecosystem are characterized as lowland and upland varieties respectively.

During the 2004 growing season, all collected 206 lowland and 74 upland accessions were grown in lowland and upland nurseries established on the experimental fields of the RRS at Rokupr. Because collected seed quantity for most accessions was small, the primary purpose for the nursery was to multiply seeds of all the samples that were to be used for more adequate experimental trials in the following year. The applied field practices followed the protocols for rice nurseries as defined by the RRS (RRS, 1980). For each of the accessions in the nursery, qualitative morphological scores for 12 traits were obtained (Appendix 3). Data scoring protocol was adapted from the standard evaluation system for rice of the International Rice Research Institute (IRRI) descriptor list (IRRI, 1980), with minor adjustments made for ease of scoring. Based on the preliminary data obtained, heterogeneous seed lots were identified and misplaced samples that had been allocated to the wrong ecosystem were reassigned.

In 2005, seeds quantities of each rice sample obtained from the 2004 nursery were reasonable enough to allow a complete field trial. To accommodate for the large sample size an augmented field design was adapted from Walter and Reynolds *et al*. (2001). The purpose was for morphological characterization and evaluation, following specific design protocols that were adopted from previous WARDA/RRS field trial outlines conducted for similar genetic resources experiments (RRS, 1991; RRS, 1993). Since this protocol did not include replication of sample units, standard reference accessions were replicated to test variation between plots. Our motive for using these protocols was to provide some basis for comparison with the earlier experiments conducted by WARDA/RRS staff (see chapter 7).

Each accession was allocated to plots of 1 m long, arranged in three rows, with a spacing of 25 cm between hills and 50cm between rows. Four samples of reference accessions obtained from the RRS were used at each of the trial sites. Fertilizer was applied in two splits of NPK 60:40:40 ha^{-1}: a first application 14 days after sowing and a second application at 45 days after sowing, i.e. just before booting.

6.2.3 Data collecting

During the course of the trials, qualitative and quantitative traits were scored separately. 12 qualitative traits were obtained by visual assessment of crop performance and character description that is presented in Appendix 3. Descriptive codes were used for the traits with discontinuous variation or expression that could not be easily translated into numerical units, for example, culm strength and panicle exertion. The qualitative data scored in 2005 was used to verify the data collected in the 2004 nursery. For quantitative traits, five plants were randomly selected in each plot and tagged for data collection. 16 quantitative traits were scored following the methods described in Appendix 4 and an average was obtained as plot means for each trait from the measurements of the five tagged plants. At maturity, panicles were harvested from the same plants and transported to the laboratory for post-harvest data on panicles and seeds. The traits that were chosen were consistent with farmer selection criteria and variety evaluation protocols applied before in Sierra Leone (Jusu, 2000). Samples were also attributed to either *O. glaberrima* or *O. sativa* groups by observing differences in panicle branching and ligule morphology following Sarla and Swamy (2005).

6.2.4 Data analysis

Both qualitative and quantitative data sets were used to analyse variation and relationships between the collected accessions. The reference samples included in the quantitative data set were used to estimate environmental effects between trial fields on the overall results, and for this a fixed statistical analysis was performed. The residual mean square obtained from this preliminary analysis was compared with different random models to measure environmental effects. The comparisons did not give any statistically significant differences between the replicated reference variety units, which demonstrated that the trial field was reasonably homogeneous and that the measured variation was not the result of environmental factors. The reference varieties were later eliminated from the data for they were not part of the collected samples.

A statistical analysis was carried out on the core data using SPSS software version 17.0 following the Guide to Data Analysis by Marija (2007). For each district, means, standard deviation (SD) and coefficient of variation (CV) were calculated for each trait, and the significance of the pairwise mean differences between districts was tested by using the Tuckey test for multiple comparisons. Pearson correlation coefficients were determined between the observed characters, and the traits showing the highest correlations were presented in a table.

Principal Component Analysis (PCA) of the morphological traits was conducted in order to graphically summarize the variation between lowland and upland samples using CANOCO (ter Braak and P. Šmilauer, 2002). PCA was done after standardizing the data to mean 0 and unit variance. The quantitative data were logarithmically transformed prior to standardization. Results of the analysis are presented in a distance biplot (ter Braak, 1994) with arrows for traits that point in the direction of their maximum variation and points for samples showing the variability in the sample set. Crops phenotypic diversity between samples was estimated from the variance of the PCA scores in the first two principal components.

A dendrogram was constructed using NTSYS software (ver. 2.2) for multivariate analysis (Rohlf, 2005) with the unweighted pair group method in order to explain relationships between accessions for the upland varieties, and establish variety relationships, and the relationship between the two rice species, *O. sativa* (OS) and *O. glaberrima* (OG). The varieties were prefixed “a” for Kambia varieties and “b” for Kono varieties in an attempt to distinguish between the varieties based on the districts in which they were collected.

6.3 Results

Tables 6.1 and 6.2 present, per district, the mean, range and coefficient of variation of 16 quantitative and 12 qualitative traits respectively that were used to characterize the 280 rice samples. For the quantitative traits, seedling height, number of tillers, and number of productive tillers showed significant variation between all districts, while the differences for days to germination, ligule length and grain width were nowhere significant. The differences for plant height, culm length and leaf width were significant between the Kono and Koinadugu districts, but these traits showed no significant difference between the Kono and Kambia districts. There were no significant differences for 10 out of the 16 quantitative traits between the Koinadugu and Kambia districts. No less than 11 out of the 12 qualitative traits had any significant difference between Koinadugu and the Kambia districts but there were 7 traits with significant differences for the Kono district when compared to the other two districts.

Tables 6.3 and 6.4 present the results of the statistical analysis using quantitative and qualitative data respectively to discriminate between ecosystems (upland vs lowland). Significant statistical differences for 12 out of the 16 quantitative traits were found between the varieties of the two ecosystems. The 4 quantitative traits that showed no significant differences were days to germination, leaf width, grain weight and grain length. For the 12 qualitative traits, only two (seedling vigour and endosperm type) showed no significant differences between the two ecosystems.

Table 6.1: Means, range and coefficients of variation (CV) of quantitative traits used to analyse 280 rice varieties collected in three districts. Means bearing * are significantly different per trait using the Tuckey test ($p < 0.05$).

	Kono n=102			Koinadugu n=60			Kambia n=118		
Trait	**Mean**	**Range**	**CV (%)**	**Mean**	**Range**	**CV (%)**	**Mean**	**Range**	**CV (%)**
Days to germination	4.38	4 - 5	11.14	4.32	4 – 5	10.87	4.32	4 – 5	10.86
Germination	64.17*	10 – 85	23.39	70.00	55 – 85	11.54	71.78	50 – 98	13.90
Seedling height	15.56*	9.8 – 22.7	20.17	17.10*	13.1–22.2	11.39	13.70*	9.4 – 20.1	13.64
Plant height	121.16	74.7 – 155	14.68	129.08*	84 – 161	12.18	121.73	75 – 163	14.70
Culm length	97.41	59 – 130	16.45	103.78*	55.8 – 139	15.42	96.56	48–136	17.74
Days to 50% flowering	104.02*	78 – 132	13.21	117.85	94 – 135	10.71	118.47	84 – 133	11.89
Days to maturity	133.70*	107 – 160	10.23	146.32	124 – 162	8.55	147.48	110 – 160	9.33
# of tillers	28.77*	9 – 55	54.36	44.67*	37 – 55	10.79	39.10*	13 – 52	21.15
# Prod. tillers	24.81*	8 – 50	57.67	39.17*	22 – 49	13.05	33.37*	10 – 47	23.25
Leaf width	1.41	0.8 – 2.2	22.59	1.21*	0.9 – 1.7	14.45	1.35	0.8 – 1.8	13.95
Leaf length	30.53*	13.1 – 48.6	23.06	28.17	25.5–29.8	3.63	27.94	19.3 – 45	12.11
Ligule length	1.50	0.4 – 3.2	37.74	1.42	1.1 – 1.8	10.76	1.43	0.4 – 3.3	25.98
Panicle length	24*	13 – 30	14.91	25	16–29	12	25	14 – 29	11.45
Grain weight	2.51*	1 – 4	25.54	2.20	1 – 4	27.50	2.28	1 – 4	28.03
Grain length	8.62*	6.7 – 11.7	10.59	8.03	6.1 – 9.9	9.88	8.17	5.6 – 11.5	10.94
Grain width	2.75	2 – 3.6	10.89	2.71	2.3 – 3.3	8.57	2.67	2 – 3.5	9.81

Table 6.2: Means, range and coefficients of variation (CV) of qualitative traits used to analyse 280 rice varieties collected in three districts. Means bearing * are significantly different per trait using the Tuckey test ($p < 0.05$).

	Kono n = 102			Koinadugu n = 60			Kambia n = 118		
Trait	**Mean**	**Range**	**CV(%)**	**Mean**	**Min, Max**	**CV(%)**	**Mean**	**Min, Max**	**CV(%)**
Seedling vigor	1.85	1 - 3	42.16	2.23*	1 - 3	32.29	1.97	1 - 3	37.56
Culm strength	2.66*	1 - 7	70.30	3.83	1 – 7	39.69	3.47	1 - 9	52.16
Leaf pubescence	1.59	1 - 3	47.17	1.42	1 - 3	39.44	1.68	1 - 5	54.17
Flag leaf angle	2.35*	1 - 5	56.60	1.08	1 - 5	25.93	1.37	1 - 5	56.20
Panicle compactness	2.70	1 - 5	73.70	2.0	1 - 5	87.00	2.88	1 - 9	91.67
Secondary branching	2.94*	1 - 4	22.11	2.45	2 - 3	20.41	2.38	1 - 4	25.63
Panicle exertion	2.05*	1 - 3	37.07	1.27	1 - 2	35.43	1.37	1 - 3	43.80
Shattering	2.84*	0 - 7	62.68	3.76	0 - 7	49.73	4.18	1 - 7	42.58
Awning	0.11	0 - 2	509.09	0.03	0 - 1	600.00	0.0	0 - 0	0.00
Seed coat pubescence	1.23*	1 - 2	34.15	1.0	1 - 1	0.00	1.0	1 - 2	9.00
Endosperm type	1.38	0 - 3	57.97	1.37	0 - 3	59.85	1.55	1 - 8	63.87
Aroma	0.21*	0 - 1	200.00	0.43	0 - 2	123.26	0.47	0 - 2	112.77

Table 6.3: Means, range and coefficients of variation (CV) of quantitative traits used to analyse 280 rice varieties analyzed ecosystem. Means bearing * are significantly different per trait using the Tuck test ($p < 0.05$).

	Upland n=74			Lowland n=206		
	Mean	**Range**	**CV (%)**	**Mean**	**Range**	**CV (%)**
Days to germination	4.37	4 - 5	10.98	4.33	4 – 5	10.85
Germination	64.1*	10 – 98	28.35	70.73*	50 – 85	11.51
Seedling height	13.94*	9.4 – 22.7	21.52	15.42*	11.2 – 22.2	16.86
Plant height	115*	75 – 148	16.59	125*	75 – 163	13.24
Culm length	93.61*	61.8 – 121.4	16.99	99.13*	47.5 – 139	16.86
Days to 50% flowering	99.05*	78 – 120	11.30	118.56*	83 – 135	11.33
Days to maturity	129.2*	107 – 148	8.84	147.32*	110 – 162	9.08
Number of tillers	17.04*	9 – 31	28.81	43.45*	31 – 55	12.06
Productive tillers	13.87*	8 – 24	27.47	37.73*	25 – 50	14.21
Leaf width	1.38	0.8 – 2.2	26.81	1.33	0.9 – 1.9	13.53
Leaf length	32.5*	13.1 – 48.6	26.12	27.65*	24.4 – 30.8	4.20
Ligule length	1.56*	0.4 – 3.3	48.08	1.4*	0.5 – 1.9	11.43
Panicle length	22.3*	12.7 – 28.1	17.67	25.36*	15.9 – 29.3	9.86
Grain weight	2.37	1 – 4	33.33	2.34	1 – 4	24.79
Grain length	8.4	5.6 – 10.4	11.79	8.27	6.1 – 11.7	10.64
Grain width	2.8*	2.4 – 3.6	10.36	2.67*	2.0 – 3.3	9.74

Table 6.4: Means, range and coefficients of variation (CV) of qualitative traits used to analyse 280 rice varieties analised by ecosystem. Means bearing * are significantly different per trait using the Tuckey test ($p < 0.05$).

	Upland n = 74			Lowland n = 206		
Trait	**Mean**	**Range**	**CV (%)**	**Mean**	**Range**	**CV (%)**
Seedling vigor	1.85	1, 3	42.16	2.03	1, 3	36.95
Culm strength	1.79*	1, 7	84.36	3.75*	1, 9	44.00
Leaf pubescence	1.91*	1, 3	42.93	1.49*	1, 5	51.01
Flag leaf angle	3.92*	1, 5	20.15	1.11*	1, 5	36.94
Panicle compactness	3.94*	1, 9	69.29	2.19*	1, 9	87.21
Secondary branching	3.01*	1, 4	25.91	2.46*	1, 3	22.36
Panicle exertion	2.46*	1, 3	25.61	1.3*	1, 3	36.15
Shattering	2.56*	1, 7	64.45	3.98*	0, 7	45.98
Awning	0.15*	0, 2	433.33	0.01*	0, 1	1200.00
Seed coat pubescence	1.32*	1, 2	35.61	1*	1, 2	6.00
Endosperm type	1.51	1, 8	75.50	1.43	0, 3	55.94
Aroma	0.08*	0, 1	362.50	0.47*	0, 2	112.77

Table 6.5 presents correlation coefficients of selected quantitative and qualitative traits based on the strength of their correlations. Since the whole matrix cannot be presented because of its size, 7 traits that showed a high correlation with 9 other traits are shown. The matrix shows that plant height and culm length were positively and highly correlated, and these traits together were strongly associated with days to 50% flowering and days to maturity. Days to 50% flowering also correlated highly with days to maturity, which together were strongly associated with number of tillers and of productive tillers. These in turn are both strongly correlated with culm strength, which is the only qualitative trait that showed a positive significant correlation with a quantitative trait.

Table 6.5: Correlation coefficients of selected traits that showed high correlation in characterizing 280 rice varieties. * denotes significant correlation between the traits.

	Clm.Lth	50% flw.	Mat.	#tillers	# prod.til.	Lig.lth	Pan. lth	Culm sth.	Lf.wdth
Plt. ht.	0.98*	0.46*	0.48*	0.27	0.27	0.16	0.37	-0.02	0.25
Clm lth		0.41*	0.43*	0.21	0.21	0.15	0.19	-0.05	0.21
50% flw.			0.99*	0.48*	0.47	0.11	0.42*	0.14	0.11
Mat.				0.46*	0.45*	0.13	0.42*	0.13	0.10
# tillers					0.99*	-0.04	0.39	0.44*	-0.07
# prod. til						-0.04	0.37	0.44*	-0.07
Lf.lth.						0.48*	0.17	-0.36	0.28

The redundancy analysis for quantitative traits (Figure 6.1a) showed a distinction of samples by ecosystem (i.e. upland and lowland ecosystems). In a similar manner, the analysis for qualitative traits also gave discrimination between the two ecosystems (Figure 6.1b). The first three eigen values for the quantitative traits explained 22, 20 and 14% of the variation, with days to 50% flowering, number of days to maturity and number of productive tillers giving the highest contributions to the first axis. Leaf width and leaf length contributed strongest to the second axis.

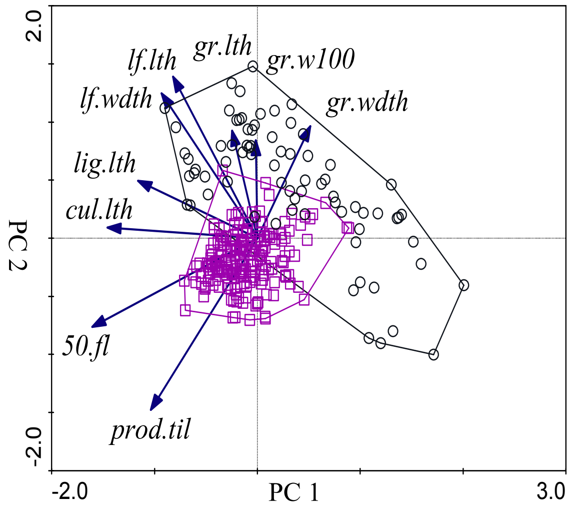

Figure 6.1a: Distance biplot of quantitative morphology data showing the difference between upland (circles) and lowland (squares) varieties in mean trait value and diversity.

For the qualitative traits the first three eigen values explained 22, 10 and 9% of the total variation, with flag leaf angle, panicle exertion, seed coat pubescence, leaf sheet colour and bran colour contributing strongest to the first axis, leaf pubescence and panicle compactness contributing strongest to the second axis.

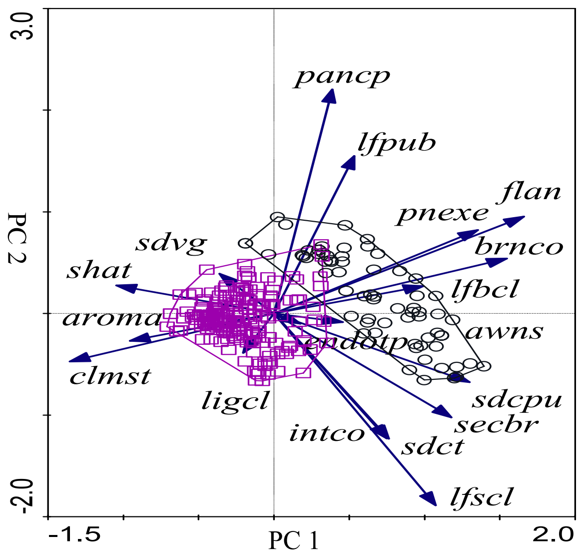

Fig 6.1b: Distance biplot of ordinal data for traits showing the difference between upland (circles) and lowland (squares) varieties in mean trait value and diversity.

The combined analysis of quantitative and qualitative traits gave the strongest discrimination between the two ecosystems (Figure 6.2a). Although the analysis of quantitative traits on the one hand and qualitative traits on the other hand yielded very similar results, the quantitative traits seemed to exhibit more variation in terms of the spread in the biplot than the qualitative ones, and the combined analysis was closer to the results of the quantitative analysis in terms of distinguishing the samples by ecosystem.

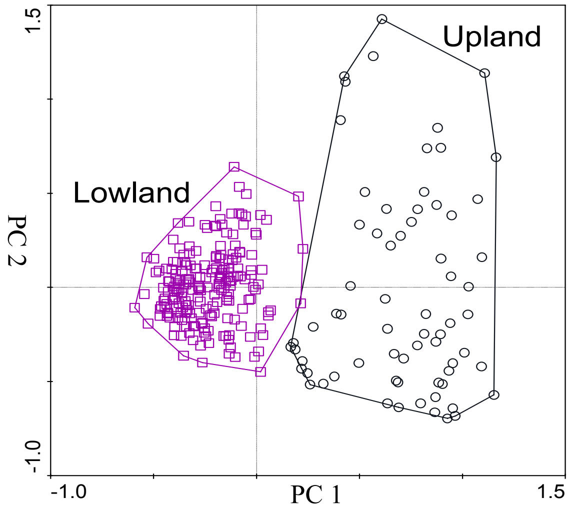

Figure 6.2a: Distance biplot of both quantitative and qualitative traits showing the difference between upland and lowland. First three eigen values explain 20, 10 and 6% of variation.

The same analysis with the combined quantitative and qualitative traits was redefined by district and Figure 6.2b gives the relationship between the varieties based on this criterion.

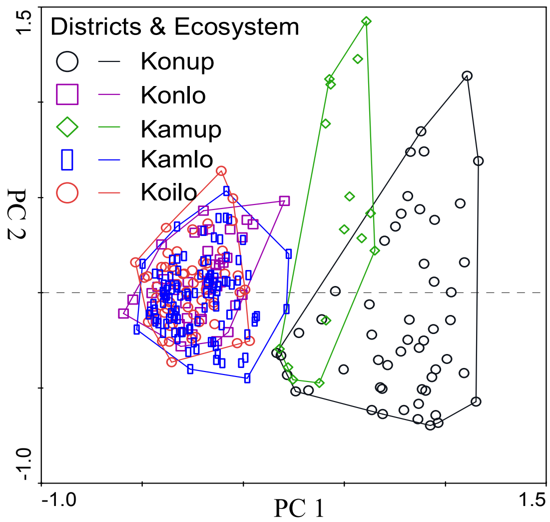

Figure 6.2b: Distance biplot of both quantitative and qualitative traits showing the difference between districts. First three eigen values explain 20, 10 and 6% of variation.

The dendrogram with upland varieties from Kambia and Kono districts is presented in Figure 6.3 showing three main clusters. Cluster 1 contains varieties that are predominantly from the Kono district except for the varieties *Binkolo* and *Pa bop* that came from the Kambia district. Very few *O. glaberrima* varieties appeared in this cluster, two sets of which, *Njewule* and *Kojogbeafehun* clustered with their pairs by name. Cluster 2 exclusively contains *O. glaberrima* varieties obtained from the Kambia district, including *Pa 3 month*, a variety reported to be a hybrid between *O. glaberrima* and *O. sativa*. In the third cluster a second set of varieties from the Kono district occurred, and these formed a group with *Rok 3* that was obtained from the Kambia district. Two possible duplicates were identified in the dendrogram: *Kongomayaka* from the Kono district and *Pa 3 month* in the Kambia district both grouping in pairs. There were some consistencies for varieties with the same names that clustered together, and this occurred mostly in clusters 2 and 3. Both rice species are present in clusters 1 and 3, where they formed distinct sub-groups.

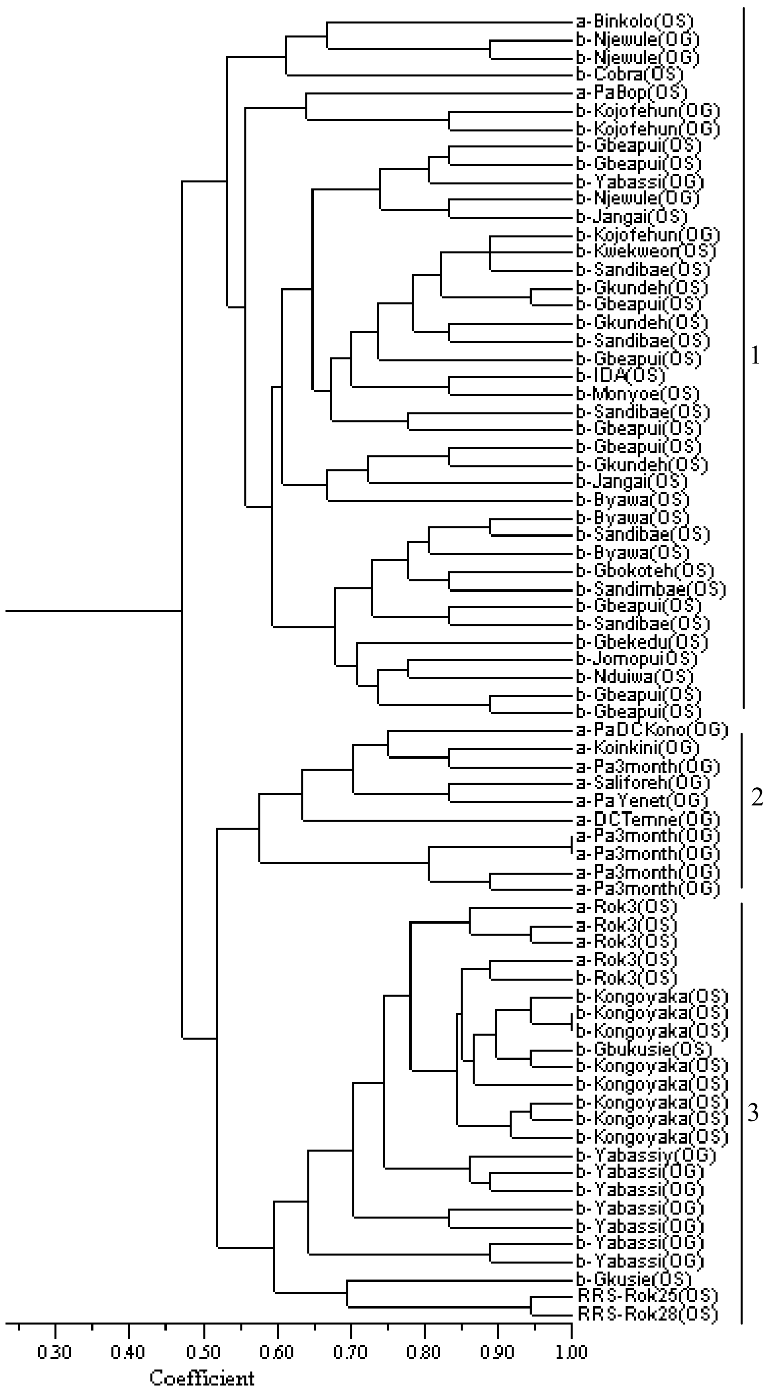

Figure 6.3: Dendrogram showing the relationships between upland rice samples and the two rice species, *O. glaberrima* and *O. sativa* obtained in two districts.

6.4 Discussion

The varieties from Kono district were distinguished from those of Kambia and Koinadugu districts for more traits (both qualitative and quantitative) than Kambia varieties were from the Koinadugu varieties. This difference is greater between Kono and Koinadugu than between Kono and Kambia. The range values for plant height, culm length and leaf width for Kono and Kambia districts showed that the two districts have similar high diversity for these traits, which is different from that of the Koinadugu district. Plant height and culm length, which correlated strongly with each other and also positively with leaf width, are traits that are associated with distinguishing lowland and upland varieties by farmers (RRS, 1991). It is therefore understood that the reason for the lack of significant differences for these traits between Kono and Kambia is most likely due to the presence of upland varieties in both districts and not in the Koinadugu district. Upland varieties have characteristically shorter plant heights and culm lengths than lowland varieties. Furthermore, there were more similarities between the varieties of Kambia and Koinadugu districts both for quantitative and qualitative traits. This could be associated with the large numbers of lowland varieties in these two districts. It is therefore clear that the Kambia district is the strongest of the three in terms of variety diversity.

Significant differences in trait expressions were demonstrated between the upland and lowland ecosystems, which demonstrates that there is more discrimination between the two ecosystems using quantitative and qualitative morphological traits than between the districts. Though both the quantitative and qualitative data expressed those differences, the quantitative traits tend to have the best discrimination potential because of the high correlation between most of the traits.

The combined redundancy analysis of both quantitative and qualitative traits yielded a much stronger discriminatory effect between upland and lowland varieties than either of the separate analysis, which demonstrated that both data sets can be used to describe rice genetic resources in Sierra Leone. For this study, we chose to continue discussing the quantitative data because it had better discriminatory potential and its output was closer to that of the combined analysis. Furthermore, the quantitative traits that explained the highest variation in the first principal component correlate strongly with one another, and are amongst the criteria used by both farmers and plant breeders to evaluate rice varieties at the Rice Research Station, Rokupr in Sierra Leone (Jusu, 2000). For example, the number of days to flowering and to maturation are important to farmers because they determine the growth duration of the variety and deal with issues such as food security, bird and pest problems, and to secure cash income generation for farmers during the growing season (Richards, 1986). These two traits are also used to determine at what stage a variety fits into the cultivation calendar. The other discriminatory traits, culm length and plant height also correlate significantly and are often used to distinguish between lowland and upland varieties. Taller plants are characteristically suited for the lowland ecosystem in order to cope with high water levels, and shorter plants are suited for the rain-fed and well drained upland ecosystems. Further to this, occurrence of variation in plant height is correlated with the method of harvesting for different farming communities, with tall plants preferred by communities that practice panicle harvest, and shorter plants suited for bulk harvesting using the sickle.

Because the traits that showed the highest level of variation are only fully expressed at the advanced stages of plant growth, by consequence seed selection in the rice crop is more effective at the later stages of crop development (Jaradat, 1991). This may explain why farmers in Sierra Leone select the plants that will provide seeds for the next growing season at the stage of crop maturity, either during or immediately before harvest (Longley and Richards, 1993). Such selection practice has resulted in favourable outcomes in other inbreeding cereals, such as spring wheat (Wong and Bakker., 1989). Early expressed traits like germination percentage, seedling vigour, and seedling height are too early in the growth circle for any meaningful selection outcome.

The redundancy analysis distinguished between upland and lowland varieties in a manner that reflects the principal rice growing ecosystems in Sierra Leone. Rice is the only crop that is capable of growing in all the major agro-ecosystems in the country, and it is believed that farmers take advantage of this natural ability to adapt their varieties to these ecosystems and their variable sub-systems. The biplot of each of the two groups also demonstrated inter-variety variation. This suggests that each group of varieties is capable of adapting to the numerous niches (sub-systems) occurring in each of the two major ecosystems. For example, the lowland ecosystem alone consists of up to five sub-systems, namely, the mangrove swamps, associated mangroves, inland valley swamps, riverine grasslands, and bolilands, each of which is characterized by distinct moisture regimes (Richards, 1985). However, although the lowlands present different adaptive challenges, the varieties that were collectively described by farmers for the lowland have shared common features that made them cluster together as one unit.

Similarly, the upland varieties clustered separately, which demonstrated that they possess identical morphological characteristics. Unlike the lowlands, the upland ecosystem is characterized by ecological variation in the form of differences in soil type, topography, slope, organic matter content and various levels of mineral toxicities or deficiencies. These may occur within a few meters of each other, which makes intra-variety variation a vital adaptive mechanism that enables upland varieties to survive in this ecosystem (Gauchan, 1999).

Redundancy analysis by district also showed some discrimination, but only between the sets of upland varieties. Though there is an overlap for the upland varieties, a number of the varieties from Kono appear to be different from those from Kambia. This demonstrates a regional basis for crop adaptation.

The dendrogram showing three clusters further supported the regional differences between the upland rice varieties grown in Sierra Leone. The first cluster contains varieties that were acquired from the southern regions of the Mende tribal districts by Kono farmers during the war (see chapter 4). Almost all of the varieties in this group carry names that are characteristics of the Mende tribe, suggesting that they originated in that region. The villages in the Kono district where the samples were collected share a common boundary with this ethnic group. The third cluster contains varieties that were endemic in Kono before the war, and were not lost. The two main sets of varieties that dominated that cluster, *Kongoyaka* and *Yabassi* belong to the old landrace groups of that district (Jusu, 2000). *Yabassi* is known to be popular with farmers because of the sweet aroma it produces while cooking and *Kongomayaka* is one of the *Yaka* group of varieties that is known for its wide adaptability and high yield (see chapter 5). The variety *Rok 3* clustering closely with *Kongomayaka* is believed to be evidence for the hypothesis that Rok3 is a selection from one of the variants of the *Yaka* varieties by scientists at the RRS.

Another significant outcome of the dendrogram analysis is explained in the separate clustering of the two cultivated rice species, *O. glaberrima* and *O. sativa*. While *O. glaberrima* is known to be endemic in the region, *O. sativa* was introduced into the country centuries ago. The results indicate that though both rice types are often grown in mixtures, they can still be fairly easily separated based on morphological characterization. Varying opinions are held regarding the likelihood of inter-species natural hybridisation because of the difficulties of obtaining fertile progenies. Some authorities believe that natural progenies from the two species do occur (Barry *et al.*, 2007) and indeed the variety *Pa 3 month* was identified as a possible natural hybrid sharing the characteristics of both species (Longley and Jusu, 1999). Although *Pa 3 month* appeared in a separate sub-cluster from the other Kambia varieties in cluster 2, they were much closer to the *O. glaberima* species of that district, indicating that the variety possesses more *O. glaberrima* characteristics than those of *O. sativa*, and that part of its parentage is closely related to the Kambia landraces.

6.5 Conclusion

The aim of this chapter was to provide a scientific interpretation of the nature of rice diversity that existed in the immediate post-war Sierra Leone, with samples obtained from three districts, Kono, Koinadugu and Kambia. Our results have shown that both quantitative and qualitative traits could be used to describe the genetic diversity of the rice varieties. The results from a comparison between districts revealed that Kono varieties were much more different from the varieties obtained in Kambia and Koinadugu than the Kambia and Koinadugu varieties between them, and the difference was much stronger between Kono and Koinadugu. The outstanding differences found for the Kono varieties could be partly explained by a higher number of upland varieties, and also of varieties that were obtained from an entirely different region in the country. The strongest distinction, however, was shown between upland and lowland varieties, indicating that these two groups of varieties are morphologically distinct. The overall results demonstrate that for future genetic resource studies, it is important to note both the regional and ecosystem significance of varieties.

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Chapter 7

Effects of war on rice genetic resources in Sierra Leone

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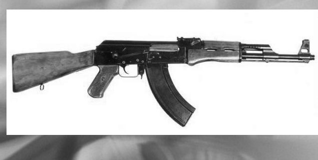

Abstract

The changes that occurred in rice genetic resources over a 30-year period in Sierra Leone (1971 to 2003) were investigated. During this period, Sierra Leone went through civil war that lasted for 10 years. The challenge was to determine to which extent any observed changes in the rice germplasm in the country were due to normal and well-known factors leading to genetic erosion, or to specific causes related to the war. Morphological traits measured showed substantial differences between the two collection periods. On average, the rice varieties in the 1970s (here referred to as pre-war) appeared to be taller, with longer leaves, requiring more days for maturation and having higher tiller numbers than post-war rice varieties. The germplasm analysis showed a more pronounced distinction between upland and lowland varieties in the samples collected in 2003 (post-war) than in the pre-war collections. Furthermore, the analysis revealed that phenotypic diversity increased in the upland varieties and decreased in the lowland ones between the two periods, and the overall post-war diversity was higher than pre-war. The observed changes indicate the need for careful future management, monitoring and improvement of rice genetic resources in the country, which include options for enlarging the diversity by reintroduction of the old cultivars currently held in gene banks either directly to farmers or through breeding programs.

Key words: Genetic resources, phenotypic diversity, rice, Sierra Leone, war, pre-war, post-war, variance

7.1 Introduction

Sierra Leone is an important rice producing country in West Africa. Its total land area under rice cultivation is amongst the highest in the sub-region (Nyanteng, 1986) and rice serves as the basic subsistence food crop and the most important source of proteins and calories for a large portion of the population (Rhodes, 2003). Rice cultivation is seasonal, and generally conducted by traditional farmers. In the process, farmers select better adapted genotypes from their varieties. Both cultivated rice species, *Oryza glaberrima* Steud., commonly known as African rice, and *Oryza sativa* L., originating from Asia are grown in Sierra Leone. They are often grown in mixtures in either of two major production systems, i.e. *the upland farming system* and *the lowland farming system* (see Chapter 2). The distinction between these systems is based on the geography and agro-ecology of the country that defines the *upland* and *lowland agro-ecosystems,* both of which are characterized by unique and specific production patterns and exploit specific rice varieties adapted to the ecosystem concerned (Due and Karr, 1973).

According to Dries (1991), upland rice cultivation has been practiced in Sierra Leone for over a thousand years, and still is the predominant production system. Plateaus, hills and slopes that depend on seasonal rainfall for moisture form the upland ecosystem, which accounts for about ¾ of the total rice production area (Kline, 1956). In addition to rice, a wide range of other food crops is grown in the upland system, including sorghum, millet, maize, cassava, beni seed and beans. The lowland agro-ecosystem includes coastal mangrove swamps, inland valley swamps, riverine grasslands, and grassy flood plains (Kline, 1956). Here rice cultivation has also been practiced, albeit on a lesser scale, since the end of the 19th century (Fyle, 1979). Production in the lowlands is characterized by a higher yield potential (Jallow and Anderson, 1985). Researchers have recognized two other major lowland ecotypes: the bolilands of the interior plains and the vast deep-water swamp ecosystems in the interior south. Together, these ecosystems account for 100,000 ha of potential rice cultivation land (RRS, 1998).

The array of both macro- and micro-environments in Sierra Leone has created the conditions for a rich agro-biodiversity, and has also substantially contributed to the local diversity of rice genetic resources (Agyen-Sampong *et al.*, 1986). Institutional research and breeding programs involving the rice gene pool in the country are dating back to the 1930s in the colonial era. In this context, the Rice Research Station (RRS) was established in 1934 as an Experimental Station with the mandate to conduct research on rice covering all major agro-ecosystems in the country (RRS, 1953). Research activities included the collection and characterization of local germplasm, but also the introduction of foreign genetic resources for crop improvement programs (Jusu, 2000). A number of these introduced varieties are believed to have survived in farmers' fields since the 1930s when exotic rice varieties were introduced by the colonial scientists (GOSL, 1953)

The most extensive expeditions set up to systematically collect rice genetic resources were conducted between 1971 and 1978. The objective was to fully capture the crop's diversity and conserving it *ex situ*. A combined team of researchers of the RRS and the West Africa Rice Development Association (WARDA), then situated in Liberia, conducted the surveys, and the seed materials collected were characterized and evaluated at RRS. The accessions were kept at the WARDA gene bank and the characterization and evaluation results documented at both institutions. A number of the collected accessions exhibited superior agronomic traits, and were subsequently used for the development of improved varieties for low-input production systems, with genotypes adapted to the various stress conditions of the different agro-ecosystems, such as salinity, iron toxicity and phosphorus deficiency (RRS, 1980).

Concerns about the loss of crop diversity formed the background for the exploration of rice genetic resources in Sierra Leone; genetic erosion resulting from factors such as deforestation, migration, soil erosion, and the traditional practice of shifting cultivation. The decade of civil war (1991 – 2002) literally devastating farming communities and production systems formed another cause for concern. The war virtually destroyed the social, economic and institutional fabric of crop production, and attacks on major farming areas caused farmer communities to migrate in large numbers to safer but more unproductive regions. It literally halted agricultural production at all levels and resulted in losses of farmers seed stocks and the disturbance of agro-ecosystems (Squire, 2001). In this context, the state of the previously rich on-farm genetic resources of both major and minor crops as a result of the war was uncertain and the question remained whether or not the war has actually reduced rice genetic diversity in the country.

This study is aimed at investigating the status of rice genetic resources after the civil war in Sierra Leone. Seeds were collected immediately after cease-fire was enforced in 2003, in an attempt to capture the resources that survived the disturbances and to determine direct effects on their diversity. We compared pre-war and post-war seed accessions using multivariate analysis to measure the difference in diversity between the two periods and between the varieties themselves. In addition, we compared the amount of diversity in the post-war accessions with reference accessions collected in the neighboring Republic of Guinea (with no war effect), by measuring variations in traits. Both analyses were intended to test two null hypotheses:

1. that rice genetic resources in Sierra Leone did not change over a thirty year period, and,
2. the 10-year war in Sierra Leone did not reduce rice phenotypic diversity in the country.

7.2 Materials and Methods

7.2.1 Pre- and post-war genetic resources

Rice accessions used in this study were collected in Sierra Leone during periods defined as pre-war and post-war. The period considered pre-war includes the years between 1970 and 1990; and the (immediate) post-war period includes the years 2003 and further. Pre-war genetic resource collections were conducted nation-wide (Figure 7.1) between 1971 and 1978. Seed accessions were stored *ex situ* both in Sierra Leone and as base collections in long-term storage facilities at the gene banks at WARDA, then in Ivory Coast but currently in Benin. Before the samples were sent to the gene banks at WARDA, they were subjected to field trials in Sierra Leone, and morphological data were obtained. The data sets including morphological information, passport data and the precise collecting locality were available at the Rice Research Station.

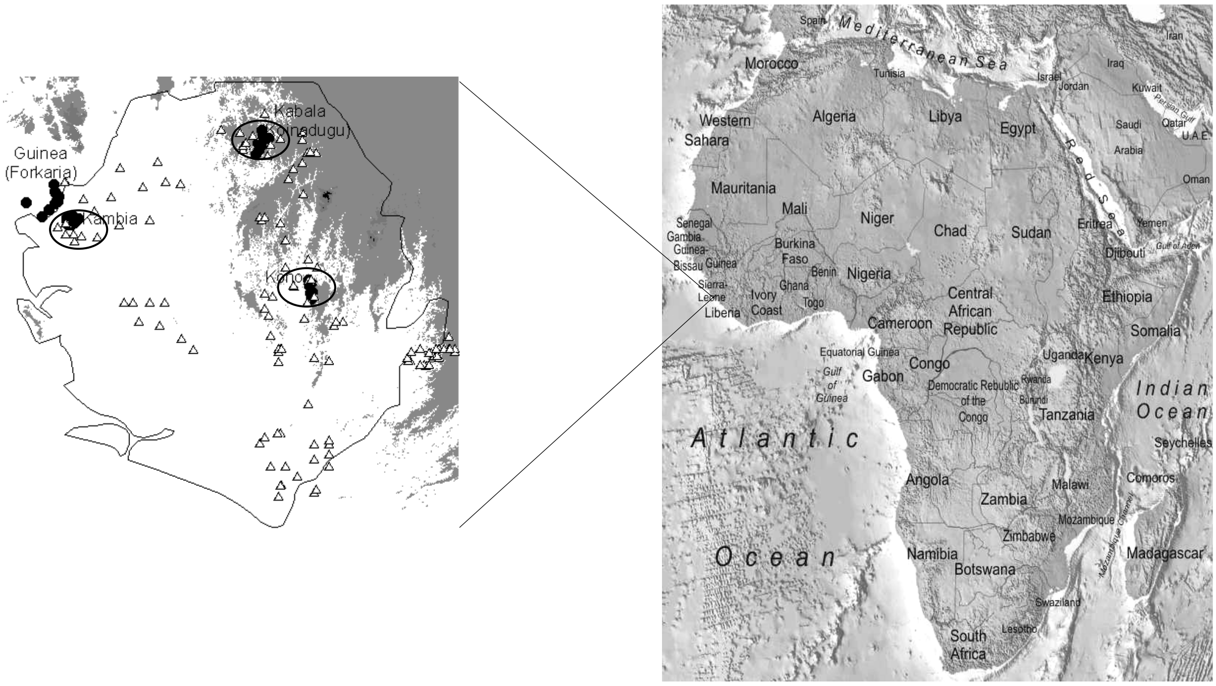

Figure 7.1: Map of Sierra Leone showing rice genetic resources collecting sites during pre-war and post-war periods in Sierra Leone. The circles show overlap of the two collecting sites

The GPS co-ordinates linked to the samples collected during the pre-war expeditions were plotted together with those of post-war samples onto the map of Sierra Leone, using ArcView software (Figure 7.1). Post-war expeditions were conducted between December 2003 and January 2004 involving three districts in Sierra Leone: the Kono district in the West, the Koinadugu district in the North and the Kambia district in the Northwest. Details of the sampling methods used are given in Chapter 3. A separate collecting mission, a repeat of the one described for Sierra Leone was conducted in neighboring Guinea in order to obtain rice samples for comparison with those obtained in Sierra Leone. The Kambia district and the region where samples were collected in Guinea, Forekaria district, share the common national boundary between the two countries.

7.2.2 Phenotypic characterization of post-war accessions

In 2005, Field experiments using the post war samples were conducted at the main research upland and lowland facilities of RRS in Rokupr. The samples were planted under rain-fed upland conditions for upland varieties, and under swamp conditions for lowland varieties. Standard field methods for rice evaluations that had been used to analyze the pre-war WARDA/RRS collections in 1978 (RRS, 1980) were copied as closely as possible. These methods included an augmented field design used at RRS for large experiments involving high numbers of samples; methods that in turn were similar to those described by Walter (1961). Each accession for both upland and lowland trials was grown in a plot of 3 rows x 1 m long with a spacing of 25 cm between hills and 50 cm between rows, and for each of the two trials, four standard controls were included in replicate. Fertilizer was applied in two splits: the first application 14 days after seeding (sowing), and the second application 45 days after seeding, just before booting. Five plants were randomly selected per sample plot and tagged for later rounds of data collecting. All measurements were obtained from the tagged plants only, and at maturity, panicles were harvested from the same plants and transported to the laboratory for post-harvest panicle and seed data registration.

All together, nine traits were scored on the post-war samples to match those of the pre-war trial data. These were culm length, number of days to 50% flowering, number of productive tillers, leaf length, leaf width, ligule length, grain weight, grain length and grain width. All trait scoring protocols and units were identical to those of the pre-war field trials. These protocols were modified versions of the UPOV descriptors and the Standard Evaluation System for rice which were developed at the International Rice Research Institute (IRRI, 1980).

7.2.3 Data analysis

All data of the varieties collected from the different districts and eco-systems were compiled, and descriptive statistics was used to determine means, standard error of means (SEM) and coefficients of variation (CV) for both pre- and post-war samples for the two ecosystems (upland and lowland). Principal Component Analysis (PCA) of the traits was conducted in order to graphically summarize the variation in trait values between pre-war and post-war samples and between lowland and upland samples using CANOCO (ter Braak and P. Šmilauer, 2002). PCA was performed using logarithmic values for all traits which were standardized to mean 0 and unit variance. The results of the analysis are presented in a distance biplot (ter Braak, 1994) with each trait represented by an arrow that points in the direction of its maximum value. Crop phenotypic diversity within sample sets was estimated from the variance of the PCA scores of samples on the first two principal components. Finally, post-war data for lowland varieties for all districts (including Forekaria in Guinea) was subjected to redundancy analysis (ter Braak, 1994) in order to investigate the systematic differences between the three districts in post-war Sierra Leone and that in the relatively safer district of Guinea. Data in this case were restricted to lowland samples because there were too few upland samples for this analysis.

7.3 Results

7.3.1 Differences in number of varieties

Table 7.1 shows the number of rice samples collected from the three districts, separated by eco-system, during both pre-war and post-war periods. The total number of samples collected during both periods was comparable: 292 pre-war and 280 post-war samples. However, pre-war collections resulted in the highest number of samples for the Koinadugu district (114) and the lowest for the Kono district (67), while after post-war collecting Kambia had the highest number of samples (118) and Koinadugu the lowest (60). For all three districts, pre-war upland samples dominated in numbers over post-war ones with the Koinadugu district having the highest number. Conversely, samples for the lowlands actually increased in numbers post-war for all three districts. The reduction in number of upland samples was more drastic in the Koinadugu district; where post-war no samples of that ecosystem were encountered. Kono was the only district to have more upland samples than lowland for both periods. For the total sum, there were more lowland samples in the post-war collections for all three districts than for the pre-war, and the Kambia district had the highest number.

Table 7.1: Number of rice samples collected during pre-war and post-war periods in three districts in Sierra Leone.

	Ecosystem	**Kono**	**Koinadugu**	**Kambia**	***Total***
Pre-war	*Upland*	63	107	99	*269*
	Lowland	4	7	12	*23*
Total		*67*	*114*	*111*	*292*
Post-war	*Upland*	59	0	15	*74*
	Lowland	43	60	103	*206*
Total		*102*	*60*	*118*	*280*

7.3.2 Differences in trait expressions between pre-war and post-war collections

The upland samples gave significant statistical differences between the means of pre-war and post-war for 6 out of the 9 traits measured (Table 7.2a), indicating substantial shift in trait expressions between the two sample sets. Rice plants were much taller, had longer and broader leaves, longer growth duration and higher tiller numbers during the pre-war periods than in the post-war period. However, there were no significant differences between the means for ligule length, grain weight and grain length for the two periods.

Table 7.2a: Means, standard error of the mean (Std. Err. Mean) and coefficients of cariation (CV) of traits in pre-war (WARDA) and post-war (RRS) rice collections for the upland ecology in Sierra Leone.

Traits	**Pre-war collections n=189**			**Post-war collections n=74**			
	Mean	**Std.err. Mean**	**CV (%)**	**Mean**	**Std. err. Mean**	**CV (%)**	**Sig. level for means**
Culm length	119.3	1.18	16.2	94.4	1.87	17.4	* * *
50% fl.	117.3	1.27	16.4	99.4	1.30	11.3	* * *
Productive tillers	23.8	0.40	27.8	14.0	0.46	28.5	* * *
Leaf width.	1.9	0.01	12.7	1.4	0.04	27.6	* * *
Leaf length	54.7	0.48	14.1	32.7	0.97	25.5	* * *
Ligule length	1.6	0.01	11.5	1.6	0.08	47.6	ns
100 Grain weight	2.4	0.03	22.0	2.4	0.09	33.0	ns
Grain length	8.3	0.04	8.4	8.4	0.11	11.6	ns
Grain width	3.0	0.01	8.6	2.8	0.03	10.0	* * *

Note: *** = highly significant at 95% confidence level; ns = not significant at 95 % confidence level.

Figure 7.2a presents the distance biplot that explains the separation between the upland varieties of pre-war and post-war as demonstrated in the differences in trait expression. The first three eigen values for the PCA explained 37, 17 and 13% of the variation respectively.

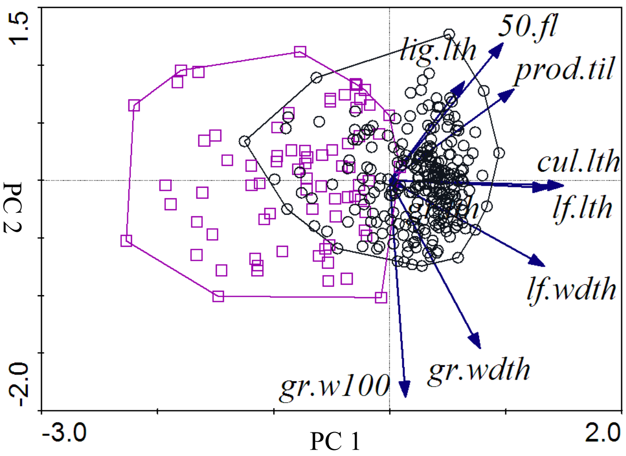

Figure 7.2a: Distance biplot of morphology for upland showing the trait difference between pre-war (circles) and post-war (squares) varieties.

A similar situation as in the upland results was observed for the differences between the means for the lowland samples, except that there was an additional significant difference for ligule length (Table 7.2b).

Table 7.2b: Means, standard error of the mean (Std. Err. Mean) and coefficients of variation (CV) of traits in pre-war (WARDA) and post-war (RRS) rice collections for the lowland ecology in Sierra Leone.

Traits	**Pre-war collections n=23**			**Post-war collections n=206**			
	Mean	**Std.err. Mean**	**CV (%)**	**Mean**	**Std.err. mean**	**CV (%)**	**Sig. level for means**
Culm length	119.3	3.15	14.39	99.85	1.16	17.29	***
50% fl.	132.9	6.21	21.11	118.1	0.94	11.23	***
Productive tillers	24.5	1.14	23.17	37.77	0.37	14.12	***
Leaf width.	1.6	0.05	14.01	1.32	0.01	13.85	***
Leaf length	53.5	0.85	10.23	27.59	0.08	4.32	***
Ligule length	1.7	0.05	18.31	1.4	0.01	11.8	***
100 Grain weight	2.0	0.08	24.02	2.33	0.04	24.91	ns
Grain length	8.0	0.13	9.29	8.27	0.06	10.57	ns
Grain width	2.8	0.03	4.99	2.61	0.02	9.68	***

Note: *** = highly significant at 95% confidence level; ns = not significant at 95 % confidence level.

The distance biplot presenting this relationship is given in Figure 7.2b, for which the first three eigen values explained 31, 16 and 11% of the variation respectively. Although the pre-war and post-war samples are separated in this plot, unlike the upland samples, productive tillers and grain length showed higher means in the post-war samples than in the pre-war ones.

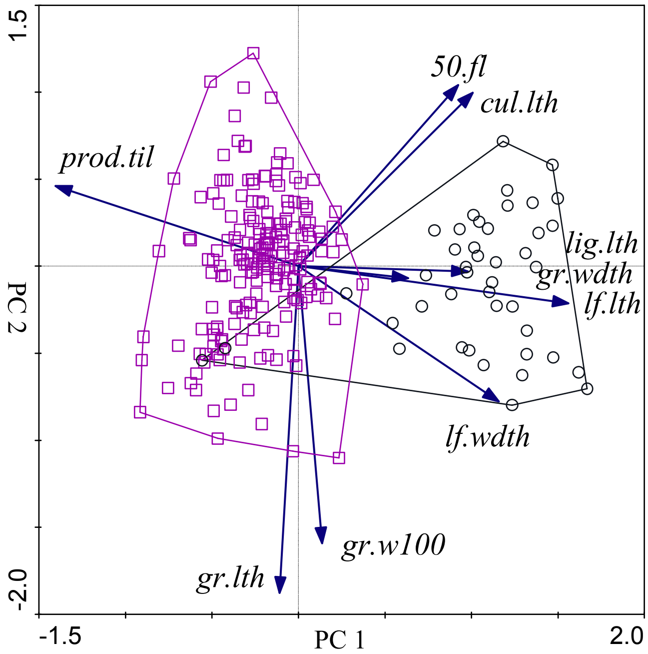

Figure 7.2b: Distance biplot of morphology for lowland showing the trait difference between pre-war (circles) and post-war (squares) varieties.

The distance biplot of the PCA for pre-war samples exhibited no clear discrimination between upland and lowland samples (Figure 7.3a). The first three eigen values for this analysis explained 26, 19 and 12% of total variation. The highest contributors to PC1 are 50% flowering, productive tillers and culm length; and to PC2 these are leaf length, leaf width, grain width and 100 grain weight.

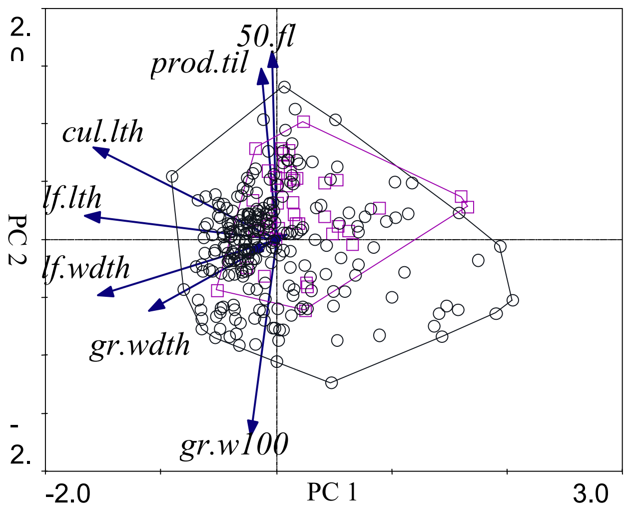

Figure 7.3a: Distance biplot of morphology for pre-war showing the trait difference between upland (circles) and lowland (squares) varieties.

Alternatively, the distance biplot for post-war samples showed clear distinctiveness between the lowland and the upland ecosystems (Figure 7.3b), with the first three eigen values explaining 22, 19 and 14% of the total variation respectively. The number of productive tillers, 50% flowering, culm length contributed highest to PC1, ligule length and grain width contributing highest to PC2.

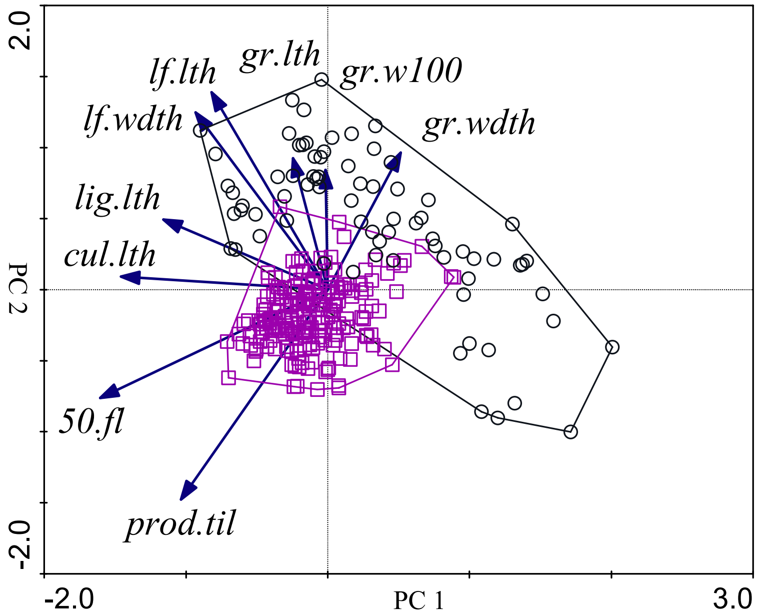

Figure 7.3b: Distance biplot of morphology for post-war showing the trait difference between upland (circles) and lowland (squares) varieties.

The combined analysis (pre-war + post-war) of all samples corrected for ecology is presented in Figure 7.4. The first three eigen values explained 25, 14 and 12% of total variation. There was a high level of discrimination between the pre-war and post-war accessions, but also a few overlaps, and pre-war trait expressions tend to overshadow those of the post-war based on mean values.

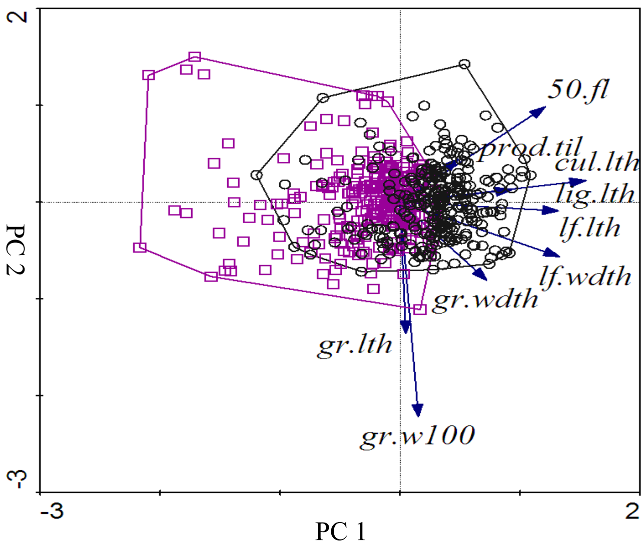

Figure 7.4: Distance biplot of morphology corrected for ecology (upland versus lowland) showing the trait difference between pre-war (circles) and post-war (squares) varieties.

Variance components calculated for pre- and post-war for the upland varieties were 26 and 62 respectively; for lowland varieties, 34 and 21, and for the combined analysis (pre-war + post-war) the variance terms were 27 and 37 respectively. Thus, it seems that phenotypic diversity within varieties has increased after the war in upland varieties, and decreased in the lowland varieties. The increase in variance for the upland post-war varieties was experienced in both the PC1 and PC2, which indicate a uniform increase in diversity. For the lowland varieties, the decrease in variance was expressed only in PC1, suggesting lower contribution to variation by the traits that featured highest in this principal component and explains the narrower spread along the horizontal axis.

7.3.3 Comparison between Sierra Leone and Guinea rice varieties

The redundancy analysis of lowland varieties for all four districts, including the Forekaria district in the Republic of Guinea, is presented in Figure 7.5. The first three Eigen values for this analysis were 7%, 2% and 1% respectively, which is very low. The traits that explained much of this variation were 50% flowering, days to maturity, culm length, plant height, number of tillers and number of productive tillers. The result of this analysis shows a strong overlap of the lowland varieties for all four districts.

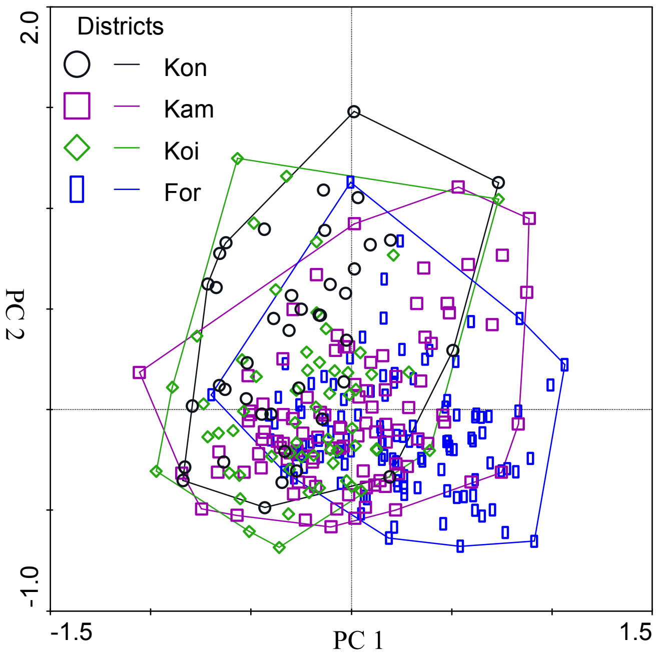

Figure 7.5: Distance biplot of morphology for post-war varieties showing the difference between districts.

7.4 Discussion

Efforts were made to ensure that expedition targets set for the post-war germplasm collections were closely similar to the objectives of the expeditions conducted pre-war, involving an attempt to capture the entire diversity of rice varieties in the regions studied. However, circumstances for the collecting missions might have been different for the two periods. The pre-war surveys were conducted during peace time when seed for every single variety was available in abundance, while during the post-war surveys seed quantities appeared to be very limited. However, the conditions of the pre-war field trials, that were done thirty years before the research reported here, were copied to the extent possible to minimize environmental effects following standard precautions described by McLauchlan (2006). To that end, all post-war trials were conducted in the same trial field sites as the pre-war ones, both for the lowland and the upland, even adopting similar land preparation procedures and closely repeating the trial protocols that were used.

7.4.1 Differences in the number of varieties
Most published records before and during the 1960s report a dominance of upland rice agriculture in the country, which explains the high number of upland varieties reflected in the pre-war collecting mission results. The decrease in the total number of upland varieties and increase in lowland varieties post-war occurred in all three districts, but this was more pronounced in the Kambia and Koinadugu districts than in the Kono district. The observed increase in the number of lowland varieties could partly be explained by farmer activity, which comes as a result of conscious farmer selection from within their indigenous varieties in favour of augmenting lowland varieties. A growing awareness of the higher yielding potential of lowland ecosystems increased farmers' interest in lowland rice agriculture, which may have lead them to select for varieties that could well adapt to those ecosystems (RRS, 1993).

Although the results suggest a growing interest in lowland varieties in the post-war era in the Koinadugu and Kambia districts, the situation was apparently different for the Kono district. In the latter district, a higher number of upland varieties compared to lowland varieties were obtained. This may be explained when we assume that farmers in this district who had lost almost all of their own varieties during the war, could primarily access upland varieties only from regions outside of their district, which were made available more readily than seeds of lowland varieties that were higher in demand (see chapter 4).

Another possible explanation for the higher number of lowland varieties is the introduction for research purposes of foreign lowland rice varieties into Sierra Leone during the period between 1970 and 1985. Most of the varieties received from IRRI in that period were screened and tested in farmers' fields, and it is believed that farmers held on to these seeds (RRS, 2000). A number of Asian rice varieties belonging to *O. sativa* were screened and adapted to the lowland ecosystems. Richards (1985) has pointed out that several of these Asian varieties are now widespread throughout Sierra Leone, and have even acquired local names. Much of these introduced varieties are of short stature, short growth duration and exhibit a high yielding capacity. The reduction in the number of upland varieties collected post-war could therefore also be explained as a result of an increasing interest in lowland farming systems especially during the war years (Koroma, 2005). In the Koinadugu district, the total loss of upland varieties was directly attributed to the war (see chapter 4).

7.4.2 Differences in expressed traits and PCA patterns
The significant differences in expressed traits between the pre-war and post-war collection samples indicate a substantial change in rice genetic resources in these three districts. Results revealed that rice plants in the 1970s were much taller, had longer leaves, required more days for maturation and had higher tiller numbers than post-war rice plants. The post-war varieties were mostly of shorter growth duration, shorter plant height and different leaf morphology compared to the pre-war varieties. In the process of variety management during the 30-year period, including the war years, the results indicate that overall genetic composition of farmers' varieties have changed considerably over this relatively short period of time. Similar changes in rice genetic diversity have occurred in other rice-based farming systems in highly marginal environments in West Africa (Nuijten and Treuren, 2007). These changes may have been caused by the introduction of new cultivars (Dennis, 1988), as a response to changes in

production systems (Dries, 1991), and in response to the need to select rice varieties well adapted to the specific conditions in the ecosystem (Richards, 1985).

The differences and similarities that existed between the varieties of the upland and lowland ecosystems in the two periods were also revealed by the redundancy analysis. The lack of a clear separation between pre-war upland and lowland varieties suggests that farmer variety management and selection during that period was based on objectives not directly associated with optimal ecosystem adaptation. In other words, farmers cultivated the same varieties either in the upland or lowland systems. However, the post-war analysis presented a clear distinction between upland and lowland varieties. Such changes may point at increasing selection for adaptation to the distinctive ecosystems, and such development is consistent with universal selection practices of traditional farmers, often focusing on optimal adaptation to their own farming system (Goncharov *et al.*, 2007; Ross-Ibarra, 2007); in the Sierra Leone case this might have involved selection for salinity tolerance (Flowers, 2005) and for iron toxicity tolerance (Yang, 2006) relevant in mangrove and inland valley lowland ecosystems respectively. In each of these cases, however, a shift in the genetic composition of rice varieties occurred, and the changes possibly have involved the loss of genetic information as a result of negative selection against unwanted traits (Crossa, 1989).

Diversity in terms of variance between pre- and post-war varieties seems to have increased for upland varieties, and decreased for lowland ones. The increase in upland variety diversity could be explained by reasoning that Sierra Leone had a strong upland rice culture before the war. As a consequence, a wide diversity was needed to support cultivation in the uplands because of the diverse nature of this ecological zone. Farmer exchange of rice varieties was common as a way of meeting the ecological challenges, and this could be supported from the number of upland varieties that were obtained by Kono district farmers from other regions during the war (Chapter 4). There is also evidence that the RRS rice breeders introduced a number of upland rice varieties into Sierra Leone from neighboring Guinea and Liberia. Therefore, although war-related losses were high for upland varieties, the genotypes maintained high diversity for adaptation.

For the lowlands, the decrease in post-war diversity suggests a possible backlash of the outcome of farmer selection. From our analysis, variation was very low for the traits that contributed to PC1 for post-war lowland varieties. These traits include culm length, 50% flowering and productive tillers, which are among the traits for which selection pressure was high. It is likely that farmer and research-led selection of suitable cultivars for higher yield components and shorter duration in the lowland ecosystem has actually contributed to a reduced diversity. There is evidence for such loss, at least for specific traits (Crossa, 1989). The increase in the number of lowland varieties, which may have been the results of such intensive selection, and also the introduction of a large number of exotic Asian genotypes, is therefore not reflected in increased phenotypic diversity. However, total diversity for rice varieties did increase in the post-war samples, which can possibly be attributed mostly to the upland varieties.

Our analysis revealed that combining pre-war and post-war diversity could result in a greater variation in the rice genepool. This suggests that maximum diversity for rice in Sierra Leone can be restored if the germplasm stored in the WARDA collections were re-introduced into Sierra Leone farming systems.

7.4.3 Comparison between Sierra Leone and Guinea rice varieties
A comparative analysis between the post-war rice accessions obtained in Sierra Leone and the contemporary rice varieties from the reference region of neighbouring Guinea, Forekaria, showed no substantial differences in the number of varieties present, for example between Kambia and Forekaria. Furthermore, the PCA revealed an overlap in phenotypic diversity of the Guinea lowland samples with the samples collected in the three districts in Sierra Leone. This may be explained by way of reasoning that within the likelihood that a number of rice varieties were lost in all of the districts during the war, the level of diversity within rice varieties in Sierra Leone remained similar to those in neighbouring Guinea. This suggests that genetic diversity for the lowland varieties was not drastically affected by the war. For the upland varieties on the other hand, the fact that the Koinadugu district lost all of its upland varieties suggests severe loss of genetic diversity in that region.

7.5 Conclusion

There is reason to reject the first null hypothesis for this research based on the observed changes in rice genetic resources over the 30-year time period. The changes were exhibited at three levels: i) the reduction in number of varieties in the upland ecosystems, ii) the increase in number of lowland varieties and iii) the temporal shift in expressed traits associated with farmer selection and possibly the introduction of exotic genotypes. The strongest evidence of variety loss as a consequence of war was observed in the upland varieties in the Koinadugu district. Alternatively, there is reason to accept the second null hypothesis because the results of this study presented an overall increase in phenotypic diversity in post-war rice varieties. However, when considered separately, the increase in diversity was pronounced in post-war upland varieties despite the reduction of the number of varieties for this ecosystem, and an actual decrease in the diversity of lowland varieties despite their increase in variety number. Nevertheless, the reasons for these observations could not be directly associated to the war. Our results suggest that greater diversity in the national rice gene pool could be achieved if the varieties held in the gene bank at WARDA were re-introduced into the rice-based production systems of the country. This could be undertaken either through direct germplasm introduction to farmers who could conduct on-farm trials and select varieties best suited for their purposes, or through plant breeding programs at RRS. This research has also enabled expansion of the existing *ex situ* rice collections, as newly collected accessions from all three study districts are presently stored as safety duplicates at the gene bank of the Centre for Genetic Resources in the Netherlands (CGN).

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Chapter 8

Effects of war on rice genetic resources in Sierra Leone

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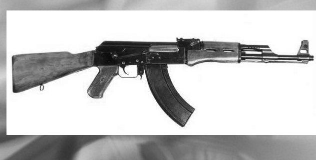

Abstract

Three separate investigations were conducted using AFLP® markers to determine the diversity and relationship among farmers' rice varieties. The first involved 35 samples of 10 varieties that were used to examine intra-variety diversity as a means of determining the occurrence of genetic exchange as an effect of the practice of mixing different varieties by farmers during cultivation. The results indicated that the rice varieties possess different levels of intra-variety variation, whereas inter-variety diversity was high enough to distinguish one variety from the other. An AMOVA analysis revealed that 38% of the total variation occurred within varieties, and 62% between varieties. The second investigation involved 21 varieties to determine the consistency of naming of varieties by farmers. The results showed that 1) there was consistency in the naming of traditional varieties, and 2) there were inconsistencies in the naming of newly acquired varieties and cultivars. The third investigation tested the identity of varieties carrying the same names collected across the border in Guinea. The results indicated no close genetic relationships between the varieties across the border despite similarities in their names. In general, a narrow genetic basis of rice types grown in Sierra Leone was revealed, as the tests showed that genetic similarities among them were very high.

Key words: AFLP®, rice, Sierra Leone, genetic variation, landraces, variety names

8.1 Introduction

Rice has been cultivated in Sierra Leone for over a thousand years under low input farmer-managed conditions. Since few centuries, both cultivated rice species, *Oryza glaberrima* Steud. and *O. sativa* L. are grown throughout the country, *O. glaberrima* having been domesticated within the West African region and *O. sativa* originating from Asia (Sarla and Swamy, 2005). The higher productivity of *O. sativa* compared to *O. glaberrima* is the reason why in the entire West African sub-region *O. sativa* is steadily replacing *O. glaberrima*. Traditional farmers who want to maintain their landraces because of their specific taste or their performance in specific habitats, often manage a wide diversity of varieties of both rice species. This practice has a profound positive effect on rice genetic diversity (Jackson, 1997). Because of the strong position of rice in the culture of Sierra Leone, it has become home to the largest national rice research station (RRS) in the entire sub-region.

In Sierra Leone, rice varieties are described using different terminologies: "landraces" (or traditional varieties) for those varieties that have existed in a region longer than farmers can remember, "new varieties" for varieties that have been introduced in a region within approximately the last 2 decades, and "cultivars" for varieties that are developed from plant breeding programs at the Rice Research Station in Rokupr or other breeding institutions. The term "farmers' varieties" refers to either or all of these categories in the possession of a farmer or group of farmers. It is common practice that farmers keep more than one category of varieties in their seed stocks. Scientists at the RRS often regard farmers' varieties as "impure", because during seed maintenance conscious mixing may occur (Jusu, 2000).

The usual cultural practice of traditional rice farmers in Sierra Leone, like in other parts of West Africa, is the cultivation of different rice varieties in mixtures (Clawson, 1985). Farmers deliberately mix two or more varieties and plant them in the same field. This is a centuries old traditional way of rice cultivation and is practiced in all major rice farming systems in the country. A number of advantages are supposedly associated with this practice: 1) a reduction of epidemic disease incidences (Zhu *et al.*, 2000), 2) creation of a buffer mechanism against total crop failures (Brown, 1983), and 3) much higher yields obtained in stress environments (RRS, 2000). In Zhu et al (200) it was also established that mixtures of different varieties of cereals under cultivation are more productive than when planted as single varieties because of the three reasons above. However, a profound knowledge of the effects of deliberate mixing of rice varieties on the genetic composition of the included varieties is still lacking.

Another well known aspect of rice cultivation is the use of folk nomenclature for variety identification purposes. Rural communities identify the varieties, especially landraces, in their possession by using specific names. This cultural practice may provide insight in the genetic diversity of rice within the region (Rao *et al.*, 2002). Many of the rice varieties grown in Sierra Leone today can be recognized as landraces, and the systematic identification of the varieties by specific names is a very important aspect of overall crop management. Several varieties that have been dispersed through farmers exchange mechanisms have specific names, which sometimes remain unchanged across the region. It has remained unclear whether these varieties maintain their genetic identity, whether the genetic variation of these varieties is influenced by dispersal patterns, and whether the names linked to specific phenotypes remain identical and could be used to assess the available rice genetic diversity in a particular region. Such an assessment can be considered vital because Sierra Leone farmers are purposely use specific variety names when they describe their crop diversity. However, it was observed before that genotype differences are known to occur between rice varieties carrying the same name and many of the names given to varieties are based only on specific morphological traits (Busso *et al.*, 2000). One of the aims of the research described here is to investigate how the names given to varieties in Sierra Leone may contribute to the assessment of genetic diversity in specific regions, and how material with the same names relates to one another genetically. The results provide insight in the question whether monitoring variety naming by farmers results in an over- or underestimation of the actual genetic diversity.

Some variety names that are common in Sierra Leone have also been encountered across the international border, in neighbouring Guinea, and the general understanding (from the names) is that these varieties originated from Sierra Leone (Jusu, 2000). Further evidence from literature suggests that cross-border farmer exchange of rice varieties occurred regularly, even during the Sierra Leone civil war (1991-2003), with earlier exchanges dating back some forty years (RRS, 1998). It is not known, however, whether the varieties now identified by the Guinean farmers with the same names, as those in Sierra Leone are genetically identical. Experimental research appeared therefore indispensable in order to investigate the genetic relationship between varieties carrying the same names in both countries.

Until now, all research conducted at the RRS on rice genetic resources are based on morphological characterization, often at the population level. Using only phenotypic evaluation, the estimation of variation often appears to be an approximation (Xie *et al.*, 2000). New techniques, like the AFLP technology, have been effective tools for the study of relationships within and among rice varieties (Caicedo *et al.*, 1999; Vos *et al.*, 1995; Yoon *et al.*, 2000) and are being used extensively for studies on plants genetic diversity and variety identification (Maughan *et al.*, 1996). The present study was designed to assess genetic diversity of farmers' rice varieties using the AFLP technique with the following objectives: (1) to investigate the effect of the farmers' mixing practice on the genetic homogeneity of varieties; (2) to investigate the genetic identity of varieties provided with identical names, including varieties with the same names found across the border shared between Sierra Leone and Guinea.

8.2 Materials and methods

8.2.1 Seed collecting and sampling
All rice accessions used in this study were farmers' varieties collected during field expeditions conducted in 2003/2004. The expedition sites were located in three districts in Sierra Leone, i.e. Kono, Kambia and Koinadugu, and a fourth district in Guinea, i.e. Forekaria. In each district, accessions of rice varieties were collected in ten pre-selected villages. During the field expedition and interviews, close attention was given to variety identification based on farmer protocols for the naming of varieties. Collected accessions were labeled and packed for transportation to the Netherlands where they were kept at –20ºC, including for long-term storage purposes. For each AFLP analysis, subsets were selected from the total collection based on the objective and criteria set for the experiment. Seeds were germinated on filter papers in Petri dishes. Plants were grown for three weeks until the three-leaf stage at which time they were cut just below the third leaf. Separate investigations were conducted based on the objectives.

8.2.2 Intra- and inter-variety variation
Ten varieties were selected to investigate variation within and between farmers' materials (Table 8.1). Between two and five seedlings were obtained from each variety depending on the number of healthy and robust plants available and DNA was extracted from each seedling separately, giving 35 DNA unit samples. Because seeds were obtained directly from farmers in a post-war situation, seed viability of most accessions was poor, resulting in low germination percentages. For this reason, the target of five seedlings per accession for this analysis was not realized.

Table 8.1: List of varieties used in AFLP analysis to investigate intra- and inter variety variation.

No.	Variety	District	# Seedlings	Remarks
1.	Kongomayaka	Kono	3	Landrace
2.	Mamy kuwa	Kono	4 + 2*	Landrace
3.	Sandibae	Kono	2	Obtained from region outside Kono
4.	Sinuwa	Kono	3	Obtained from region outside Kono
5.	Wusii	Kono	3	Obtained from region outside Kono
6.	Pataim	Kambia	2	Landrace
7.	Rok10	Kambia	2	RRS cultivar
8.	Payenet	Kambia	4 + 1*	New variety in region
9.	Marobia	Koinadugu	4	Landrace
10.	Soronkadi	Koinadugu	5	Landrace

* the additional samples were added because they showed morphological differences from the other members of the variety.

For two varieties, *Payenet* and *Mamykuwa,* some seeds appeared phenotypically different from the majority of the seeds of those varieties. For *Payanet*, the seeds that were found to be different were labeled Payenet_b, while the seeds representing the majority of seeds in the accession were labeled Payanet_a. Similarly, for *Mamykuwa*, seeds with two different morphologies were tested separately, Mamykuwa_A and Mamykuwa_B.

8.2.3 Genetic identity of synonymous varieties
Thirty-seven accessions that had 18 distinct variety names in total were used to determine the genetic identity of varieties with the same names obtained from different villages or districts. Among the accessions were landraces, new varieties and cultivars bred at the RRS (Table 8.2;

see also chapter 5). Each variety name occurred at least twice in the experiment, except for Rok 10, a cultivar, which consisted of only one accession and was included to determine whether it would be identical to any of the other cultivars or landraces, as the seeds of Rok 10 showed some morphological features similar to those of some landraces (RRS, 1998).

Table 8.2: List of varieties used in AFLP analysis to investigate synonymous varieties.

No.	Name	# samples	Districts		Remark
1	Buttercup	2	Kambia	Kambia	Landrace
2	Chinese	2	Kambia	Koinadugu	New,
3	Gbasiyin	2	Kambia	Kambia	Landrace
4	Gbeapui	2	Kono	Kono	Landrace, obtained from another region
5	Kojogbeafehun	2	Kono	Kono	New variety, obtained from recently
6	Kongomayaka	3	Kono	Kono	Landrace
7	Kwatikkundor	2	Kono	Kambia	Landrace
8	Marobia	2	Koinadugu	Koinadugu	Landrace
9	Nerica	2	Koinadugu	Koinadugu	Cultivar
10	Pakolma	2	Kambia	Kambia	New variety, named after farmer
11	Pataim	2	Kambia	Kambia	Landrace
12	Pamuslim	2	Kambia	Kono	New variety, named after farmer
13	Rok 3	3	Koinadugu	Kambia	Cultivar
14	Rok 4	2	Kono	Koinadugu	Cultivar
15	Rok 5	2	Koinadugu	Kono	Cultivar
16	Rok 10	1	Kambia		Cultivar
17	Soronkadi	2	Koinadugu	Koinadugu	Landrace
18	Yabassi	2	Kono	Kono	Landrace

For each variety, up to five harvested seedlings were bulked together and DNA extracted. Because varieties were collected from different locations, they were each labeled with a pair of numbers; the first digit indicating the district and the second digit representing the village. For example, the Chinese variety labeled 31 came from the same district and village as the Nerika variety labeled 31, but the Chinese variety labeled 11 is from a different district and village.

8.2.4 Inter-regional genetic variation

Twelve accessions comprising six varieties from the Kambia district in Sierra Leone and six accessions carrying the same names obtained from the Forekaria district in the Republic of Guinea were selected for this investigation. The objective was to investigate the genetic similarities between varieties with the same name (Table 8.3). Five seedlings were obtained from each of the accessions and bulked for DNA analysis.

Table 8.3: List of rice samples with similar names obtained from Kambia (Sierra Leone) and Forekaria (Guinea).

No	Variety name/district/country	
	Kambia (Sierra Leone)	Forekaria (Republic of Guinea)
1	Nerika	Nerika
2	Pa muslim	Pa muslim
3	Rok 5	Rok 5
4	Pa kolma	Pa kolma
5	Pa taim	Pa taim
6	Sinuwa	Sinuwa

8.2.5 DNA analysis
The AFLP technique was applied as described by Vos et al., (1995) with minor modifications. DNA was isolated from seedlings by using the Qiagen DNeasy Plant Mini Kit and subsequently digested. Subsets of fragments were multiplied using two primer combinations E13 (E-AG) / M49 (M-CAG) and E13 / M51 (M-CCA). The results were scored using the Quantar software as outlined in Geerlings et al. (2003).

8.2.6 Data analysis
For the test directed at a comparison of intra- and inter-variety variation, an analysis of molecular variance (AMOVA) and genetic distances based on simple matching was conducted for all pairs of samples. This was done to compare molecular variance components at two levels, i.e. within samples of individual varieties, and between samples of different varieties, and variance was tested for significance by a non-parametric re-sampling approach described by Excoffier et al., (1992). For each test cluster analyses was performed using the unweighted pair-group method with arithmetic averages (UPGMA) using the Nei and Li distance measure in TREECON 1.3b (Van de Peer and Wachter, 1994).

8.3 Results

8.3.1 Intra- and inter-variety variation
The AMOVA analysis showed significant levels of variation both between and within the varieties tested, with 62% of the total variation expressed between varieties and 38% within the individual varieties.

The UPGMA analysis resulted in a dendrogram (Figure 8.1) showing that, in general, the genetic distances between the varieties were larger than the distances between individual seeds of a variety resulting in a clustering of the representatives of each individual variety. The only exception appeared to be the *Wusii* variety, two of whose members grouped together associated with representatives of the *Soronkadi* variety, while the other grouped with the *Marobia* variety. Identical genotypes were observed only for the *Sinuwa* variety, while all other varieties showed some level of intra-variety variation.

The subset of *Payanet* seeds that had shown aberrant morphological characteristics (Payanet_B) was not substantially different from seeds showing the major phenotype of this variety. In contrast, the two *Mamikuwa* subsets that were morphologically distinct showed a substantial genetic distance from each other than the seeds in the subset containing the rest of the variety. However, all tested individuals of this variety remained more similar to each other than to individuals of any other variety.

8.3.2 Genetic identity of synonymous varieties
The measured genetic similarities of the varieties carrying the same name are presented in Figure 8.2. The UPGMA revealed that the different collection samples of seven (shaded in figure) out of nine landraces (*Kongomayaka, Soronkadi, Buttercup, Pataim, Marobia, Kojogbeafehun, and Gbeapui*) clustered by name, even when originating from different villages or region. However, seeds of different samples of each of the varieties *Kwatikkundor, Pa Kolma*, *Pa Muslim* and *Chinese* did not cluster together. Most of the *Rok* cultivars appeared in cluster 1, except *Rok 10* and *Rok 5* that appeared in cluster 3, and *Rok 3* in cluster 5.

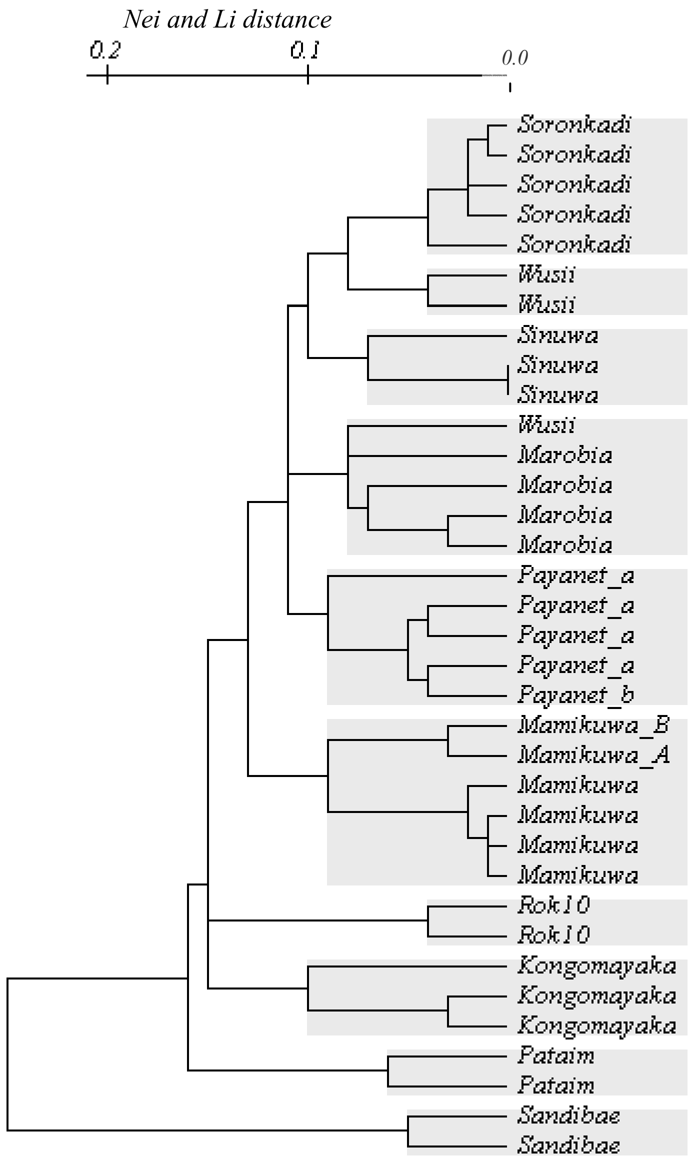

Figure 8.1: Dendrogram showing intra-variety variation of 10 farmers' rice varieties in Sierra Leone.

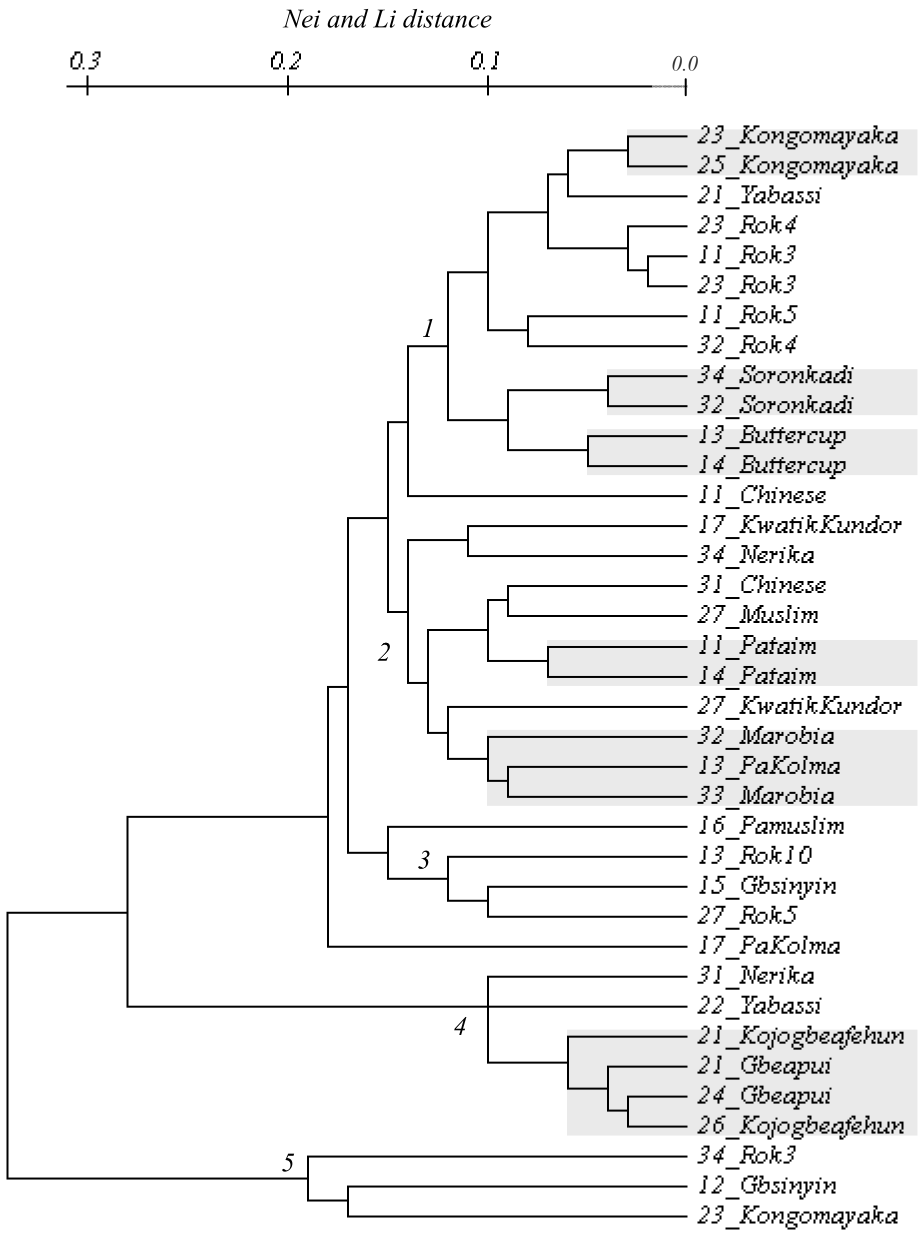

Figure 8.2: Dendrogram showing genetic similarities of 21 synonymous farmers' rice varieties in Sierra Leone obtained from different villages and districts.

8.3.3 Inter-regional variety variation

The relationship between varieties with the same name collected in Sierra Leone and Guinea is given in Figure 8.3. The dendrogram showed two major clusters of most varieties, with three remaining varieties placed at a somewhat larger distance from the two major clusters. In the first cluster, three varieties from Guinea clustered with two from Sierra Leone, and in the second cluster, three Guinea varieties clustered with one variety from Sierra Leone. However, representatives of the varieties with the same name obtained from the two countries did not cluster together, which suggests that they are genetically different.

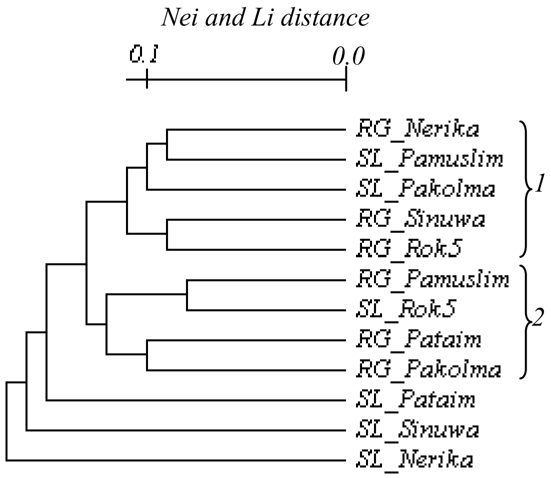

Figure 8.3: Dendrogram showing genetic similarity between farmers' rice varieties collected in Guinea and Sierra Leone.

8.4 Discussion

8.4.1 Intra- and inter-variety variation

Nine out of the ten varieties analyzed showed a high level of genetic similarity within each variety. The relatively low level of genetic similarity between varieties showed that farmers' varieties are generally readily distinguishable from each other. This observation demonstrates that the farmers' practice of mixing varieties during planting does not drastically decrease the genetic homogeneity of individual varieties. In other words, our results indicate that the practice of seed mixture does not necessarily result in genetic heterogeneity of farmers' varieties.

Farmers in Sierra Leone often practiced the strategy of intra-specific rice cropping, whereby seed of two (or more) carefully selected varieties, often including both landraces and cultivars, is intentionally mixed for cultivation (Longley and Jusu, 1999). This strategy is primarily to mitigate threats to yield stability and to increase harvest security (Teshome *et al.*, 1999), and further presents the possibility of simultaneously adapting various varieties to different ecosystems for sustainable production (Almekinders, 2001). It also improves disease management especially when different levels of resistance are present in the different varieties (Zhu *et al.*, 2000), and may result in higher yields (RRS, 2000).

Sierra Leone farmers also show preferences whereby the high yielding abilities of cultivars on the one hand and some favored qualities (taste, aroma, digestibility, etc.) of landraces on the other hand are regarded complementary to one another (Longley and Jusu, 1999). It is generally believed that farmers' varieties stay longer in the stomach than improved varieties, which makes the farmers' varieties more attractive. By mixing two rice categories at planting time, the farmers physically combine the two sets of properties: on the one hand gaining higher yield for food security from the cultivars and on the other obtaining the desired food traits from the landraces. Our results indicate that farmers are capable of recognizing individual varieties even in mixed fields, and are able to maintain the purity of each variety.

Distinction between seed for consumption and sowing material is made at harvest time. To obtain sowing material, the farmer first walks in his field cutting healthy panicles with a small knife until the seed quantity needed for the following years' farming is obtained. When this is completed, the rest of the field is bulk harvested for production of consumption grain, during which process no effort is made anymore to differentiate between the varieties that were mixed at planting time (Jusu, 2000; RRS, 1991).

During the selection process for sowing material, farmers separate varieties from one another and save them separately, which enables them to maintain seeds with a high level of homogeneity, and to ensure the distinctiveness of each variety (Longley and Richards, 1993). Field expeditions were conducted in all the study districts during the off-season period when fields had already been harvested, and seeds for the next growing season had been separated. It is therefore probable that the high level of homogeneity of each of the varieties analyzed in this study results from the fact that obtained samples were derived from farmers' sowing materials, and not from the entire farmer seed store. Another possible explanation for the high level of homogeneity encountered is that the number of varieties and seed quantities that were in the possession of farmers was still very limited in the initial post-war period facilitating careful farm seed management. The seeds of the *Wusii* variety, however, present a case different from the others as they clustered closely with varieties from the other two districts.

Although analysis for intra-variety variation revealed a high degree of genetic similarity for the analyzed seeds of each variety, most of them showed some level of intra-variety variation, which demonstrates that in Sierra Leone the chance of obtaining completely homogenous farmers' rice varieties (although an inbreeding crop) are small. Within variety diversity has been reported for *O. sativa* and *O. glaberrima* varieties in Guinea and Côte d'Ivoire (Miézan K and Ghesquière, 1986). Similar observations have been reported also for modern rice cultivars, which had initially often been considered phenotypically highly homogenous (McCouch *et al.*, 1988; Xie *et al.*, 2000). Two possible causes of intra-variety variation in farmer varieties are i) the occurrence of out-crossing between rice varieties of the same or different species and, although less likely, ii) the occurrence of spontaneous mutations (Ko *et al.*, 1994). As mentioned earlier, Sierra Leone farmers have the habit of mixing varieties at planting time as a way of ensuring harvest security in case some of the varieties fail. This practice presents the possibility for natural crossing in their rice varieties, thereby generating different levels of intra-variety variation. Furthermore, new varieties are thought to evolve from such crosses, a phenomenon already hypothesized by Jusu (2000), who identified at least one variety as a natural hybrid between *O. sativa* and *O. glaberrima* that resulted from variety mixtures by farmers on the field.

The observation of morphologically different seed types in both *Payanet* and *Mamikuwa* demonstrates the occurrence of dissimilar seed types within a variety. These differences may be due to out-crossing, but also to other factors that may not be genetic at all. Studies have shown that cereals do undergo numerous gene controlled physiological and chemical changes during grain filling, development and maturation (Gutierrez *et al.*, 2007). These changes may cause morphological differences in different parts of the panicle, especially when this is accompanied with stress factors such as lack of water and excessive heat at grain filling (Mitsugu *et al.*, 2005). One of the reasons for an analysis of inter-variety variation was that farmers' seeds often show grains that are morphological different from the other seeds in the sample. In the past, these have been often regarded to be the result of mixtures by rice breeders and other scientists working with farmers. There are cases when farmers' rice seeds are obviously mixed with seeds from other varieties (Nuijten, 2005), but our results have shown that not all morphological differences in seed lots may result from actual seed mixtures.

8.4.2 Genetic identity of synonymous varieties

The genetic relationships between farmers' varieties with the same name obtained from different villages and districts have provided new insights into the consistency of variety identification by farmers. Since variety names distinguish between landraces, cultivars and new varieties, this makes farmers' variety evaluation possible. Our results demonstrate that variety names are more consistent for landraces than for varieties that are new in a region. The varieties that did not cluster by name were either cultivars or newly obtained varieties. New varieties are often given the name of the farmer who first brought it to the village, e.g. *Pa kolma, Pa muslim* (which are names of farmers), or the region from which the variety came, e.g. *Chinese* (a variety supposedly obtained from imported grains coming from China). Such varieties are given names that may not be consistent for specific identification purposes (Nuijten and Almekinders, 2008). Our results suggest that farmers classify varieties by name at two levels: on the one hand landraces are given specific names, while on the other hand, cultivars and new varieties are given the names of their owners or places of origin for a number of years before they are fully accepted and given local names (Jusu, 2000). Based on these naming principles traditional variety names in Sierra Leone could provide clues about the origin of genetic diversity of rice in a particular region. This is consistent with the findings of Rao and Bounphanousay (2002) who observed that variety names do provide clues into the genetic diversity of rice in specific regions.

8.4.3 Inter-regional variety variation

The differences between the genetic identities of rice varieties carrying the same names in Guinea as the ones in Sierra Leone demonstrated that the synonym varieties were genetically dissimilar across the geographic border region. Given that the variety names were by no means accidental, for there is evidence of farmer seed exchange (Jusu, 2000), the most reasonable explanations for the genetic dissimilarity could be attributed to the effects of migration on genotypes, genetic drift and farmer selection phenomena. Guinea farmers are not as creative with rice cultivation as their Sierra Leonean counterparts because rice is not a staple for Guinea as it is in Sierra Leone. Guinea farmers hardly conduct intensive selection, except on occasions when particular varieties is extremely mixed (Yankuba Mansaray, pers. comm.). They also conduct bulk harvesting which does not allow for adequate separation between varieties. Sierra Leone farmers on the other hand are known for careful selection of seeds of each variety at the end of every growing season. Off-types are eliminated to make sure that varieties selected are processed and kept pure. Other cultural practices such as planting density, level of variety mixtures and mixed cropping techniques have been found to be different for the two countries (Jusu, 2000). Such differences in cultural practices determine how varieties, though coming from the same region could change their initial genetic profile. This observation agrees with those of Tin *et al.* (2001) and Teshome *et al.* (1999) who found that a change in major plant management practices may lead to changes in plants genetic and morphological features over time.

8.5 Conclusion

In Sierra Leone, inter-variety genetic differences between farmers' varieties are large enough to distinguish one variety from the other, which demonstrates that the genetic composition of rice varieties is not drastically affected by the farmers' practice of planting in mixtures. At the same time, intra-variety variation may be attributed to genetic exchanges caused by this practice, but rice being an inbreeding crop, the rate of gene flow is not high enough to drastically change the genetic profiles of individual varieties. For this reason, variety names in Sierra Leone are good indicators for genetic distinctiveness as far as these names concern traditional varieties, and provide a measure of the diversity of the rice genetic resource of a given region. However, our results show that rice varieties do undergo genetic changes when they are cultivated under different cultural practices, apparent from the genetic differences measured between Sierra Leone and Guinea synonymous varieties.

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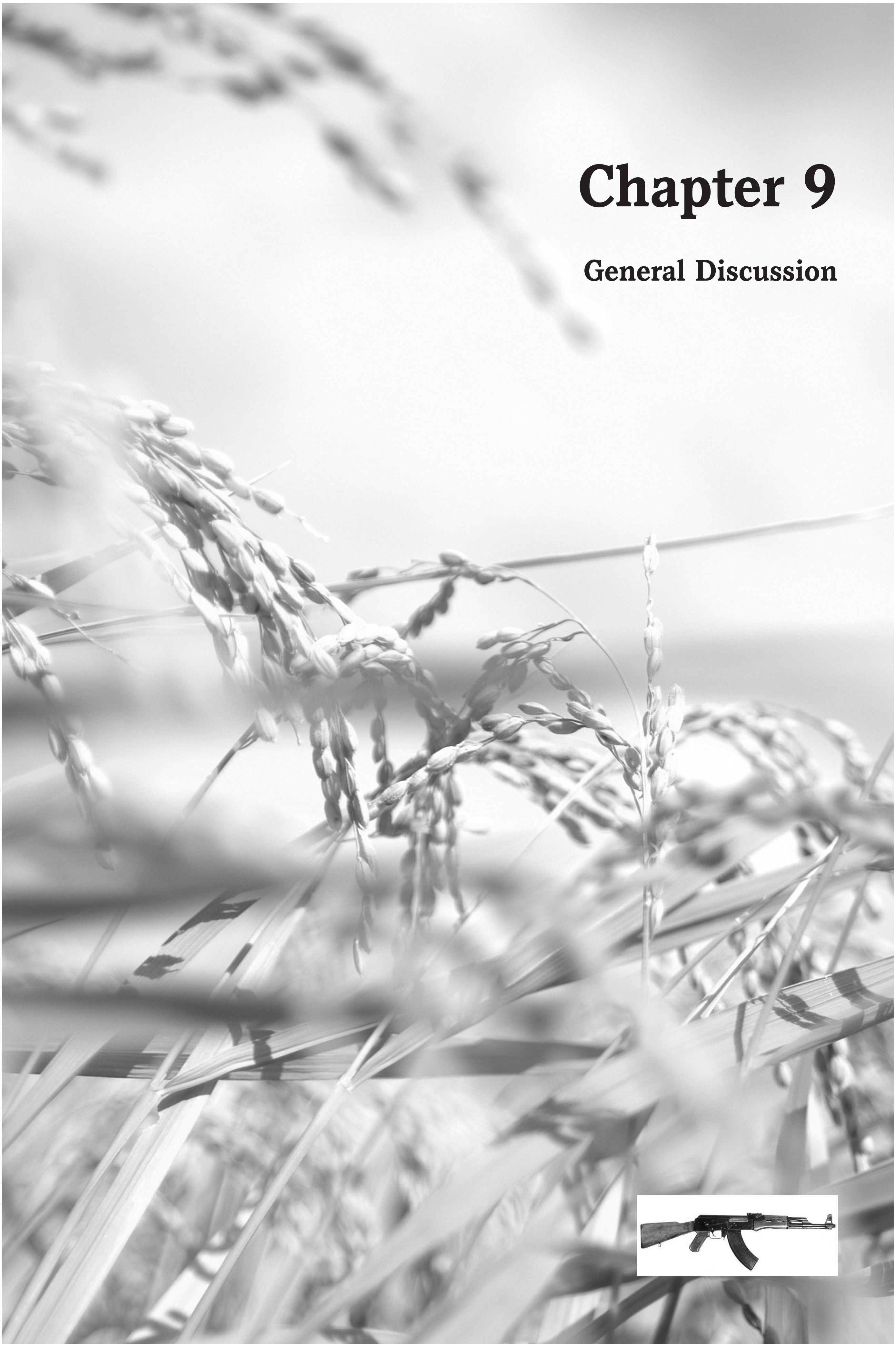

Chapter 9

General Discussion

9.1 Introduction

In this research we have tried to understand the effect of the 10-year long civil war in Sierra Leone on rice genetic resources, using farmer knowledge of the conflict and their post-war seed resources as reference. The entry point was to establish the effect of the war on the farming population, which has direct consequences on their agricultural practices and the on-farm genetic resources. Following this, we focused on the nature and width of phenotypic diversity of the different rice types that were obtained as farmer varieties during collecting trips conducted immediately after the war. The actual composition of the genetic diversity was studied in different perspectives, and comparative assessments of the resources in the pre-war and post-war situations were attempted. This chapter will highlight the main conclusions answering the questions posed in chapter 1 of this thesis. The chapter will also present a general overview of concepts that were not directly outlined in the research questions, but have been part of the major lessons that were learnt in the process. Further to this, some suggestions for future research areas are presented.

9.2 Approaches employed for post-war expedition

This study shows that when planning fieldwork in an immediate post-war environment, two major factors should be taken into account: 1) the issue of maximum security for the expedition team, and 2) the assurance of confidence of the local community from whom data is to be obtained. Requirements for extracting quality data and valuable information may differ from one region to another, necessitating the ability of the researchers to continually adapt their strategies. The time our research was conducted warranted certain precautionary measures that needed to be incorporated into the conventional expedition protocols. The most important element of the preparation for the expeditions was the training program of personnel including persons who had already gained some experiences with farmers in the post war situation in Sierra Leone. They shared different aspects of the field exercises with the expedition team, which enabled us to adopt measures such as behavioral patterns to reduce the risks of violent attacks and robbery. During the entire preparatory process, including the field pilot phase where approaches were tested after the workshop, it was realised that knowledge of both social and cultural interests of the communities would offer the best possible approach, and this became the most valuable lessons that were learnt and applied throughout the expedition.

Two social functions that were adopted in our methods, i.e. the forerunner aspect and women leading our convoy (chapter 3), had actually come from the historic contexts of war and peace building in Sierra Leone, which was presented by an elderly participant in the training/workshop. Kai Londo, Bai Bureh and Mansa Musa are war lords that featured strongly in the war history of the country, but they were also reputed for their skills in peace building after tribal conflicts. In post war situations when they sought peace with their enemies, they adopted the following practices :

- a fore-runner as a messenger of peace: a forerunner is sent ahead into enemy territory to announce a peace deal. The messenger is never attacked for he is never viewed in his own accord, but as a representative of the warlord. The message he brings back to his bosses determines whether the other side was ready for peace.
- women leading the war-lord convoy: women were regarded as the vulnerable members of society, and it is a taboo to attack them for any reason post-war. Therefore

women always led the warriors into any hostile community waiting to discuss peace; a sort of a soft approach mechanism and a message that no weapons were allowed.

The involvement of the former militia into the Kono expedition team was both a security measure and meant for confidence building in the local communities, and it was suggested at the consultation meetings with the local authorities. This however had its advantages and shortfalls. In villages where the former commander was regarded as a hero, the expedition team was safe, but there were some villages in his own region where some people remembered his harsh leadership and he was resented. He was not allowed to accompany the team in these circumstances.

For the other two districts, Kambia and Koinadugu, the use of the services of the nurse in addition to the fore-runners was very useful . All other measures that were adopted came from simple application of security measures that were discussed at the workshop and from the outcome of the pilot. This included, for example, not entering certain villages with the vehicle because of its NGO registration plate; and leaving behind all valuables including purses, wedding rings, belts, fancy clothing, etc.

9.3 Response of rice farming system during war

9.3.1 Farming systems

The lowland farming system was shown to be increasingly more favorable to farmers while the upland system was gaining less prominence in post-war Sierra Leone, suggesting that the lowlands presented the most sustainable food security system during wartime. This conclusion is based on the observed increase of the lowland varieties when compared to those of the uplands (Chapters 5 and 7). From historic records, the upland farming system dominated rice agriculture in the country until two decades ago. The greatest disadvantage of the upland system, however, is that it is characterized by shifting cultivation that involves slash and burn of primary forests. This makes it, among other activities, highly labour intensive which is not very encouraging during wartime, and is dangerous because of attracting attention (chapter 4). It is also regarded as a wasteful land use system while at the same time it generally gives lower yields than the lowland systems (Havinden, 1970). Lowland agriculture on the other hand is characterized by high production potential, which makes it attractive because of the increased focus on household food security (Johnny *et al.*, 1981).

In the face of a decline in the upland farming system, there is fear for the loss of agro-biodiversity of particular rice varieties, but also of other food crops such as sorghum, pearl millets, finger millets and a number of vegetable types that were cultivated in the upland system. Average upland farms in Sierra Leone are known to hold between 5 – 15 different crop types in a single growing season. It is therefore a matter of grave agricultural biodiversity concern when such a system is under the stress of collapse as happened in the Koinadugu district. Such loss of agricultural systems include not only the disappearance of the ecosystems, but also the disappearance of plant species, plant varieties and gene complexes that are dependent on the ecology (FAO, 1996).

9.3.2 Farmers seed systems

The results presented in chapter 4 show that the traditional seed system, especially farmer-farmer seed exchange mechanisms played an important role in preventing the loss of a number of varieties. It proved to be the most important seed management practice both during wartime and post-war because it was the only seed channel that all farmers relied on when the other components of the system, e.g. the local market, had collapsed. Longley (1997) made a similar observation during a study of seed system response in one of the districts. Despite the devastating events of the war that led to massive displacements of farmers, the few farmers that had rice varieties in their possession demonstrated potential to manage the genetic resources in a manner that was solely supported by exchange with other farmers for other seed types. Seed stores were not effective in the circumstances because they were easy targets for either rebels or soldiers that had ran out of food. To sustain farmer exchange of seeds as a viable means of preventing loss, one of the national NGOs, the Community Biodiversity Development and Conservation Project conducted by the Community Action Network, adopted a number of war time field gene banking practices wherein seeds were multiplied without attracting attention from the fighting forces. The other components of the seed system, for example the traditional market and seed loan schemes became operational only in the post-war period as a means of recovering lost varieties. This situation is comparable, for example, with the Rwandan war situation where recommendations for seed recovery included traditional seed channels which have the potential to meet the immediate seed needs of farmers (Sperling, 1996).

Though the recommendations for local seed system support and rehabilitation are similar for the two former war countries, Sierra Leone and Rwanda (other war affected Africa countries can also be included), there are very clear differences in the seed systems, which makes the Sierra Leone case very unique. Unlike many other countries that have been affected by war, Sierra Leone has never had a functional formal or market-driven seed sector for rice. In many other countries, the formal seed system is supported by multinational companies from whom farmers purchase seed at the start of every planting season. The formal seed system breaks down quickly during wars, but it has the potential to resume immediately during post-war in countries where they were well established. Both formal (for potatoes) and informal (for beans) systems were operational in the Rwanda case, which supported each other in terms of farm-level recovery (Sperling, 1997). In the case of Sierra Leone, only the informal system is functional, which makes this system all the more important.

9.3.3 Wide rice gene pool

One of the strongest factors that prevented the total loss of farmers' varieties during the war was the mere size of the rice gene pool in Sierra Leone. The genetic resource base for this crop composed of many landraces and exotic cultivars that existed in the country before the war (See chapter 2). Despite the fact that the country was a genetic hotspot for *O. glaberrima* that is known to have been domesticated in the region, a large number of foreign cultivars belonging to *O. sativa* were introduced from different countries and institutions around the world, which further contributed to the richness of genetic materials in "farmers varieties". Most of the exotic rice types are dispersed within the farming seed stock and are in cultivation to this day (Richards, 1986). Farmers have always valued specific landrace varieties for their inherent characteristics that ensured hardiness and sustainability rather than high productivity (Frankel *et al.*, 1995). Over the years preceding the war, researchers at the RRS have screened numerous exotic varieties in stress prone environments with the objective of selecting cultivars that are suitable for the different farming systems in the country and a number of cultivars were released.

9.4 Effect of war on farming communities and their rice genetic resources

The effect of war on the civilian population presented a gradient of events ranging from most severe in the Kono district, moderately severe in the Koinadugu district and comparatively less severe in the Kambia district. This created different levels of insecurity amongst the different farming communities. Although these differences existed, a similar trend emerged in relation to the farmers' seed situation, wherein a large number of farmers lost their seed lots in all three districts. Such losses of crop varieties during wars are known to be most acute when the conflicts affecting farmers in marginal areas concentrate in remote rural areas and last for a long period of time (Richards and Sperling, 1999; Sperling, 1996). That was the case in Angola (Sperling and Loevinsohn, 1993) and Mozambique (Brück, 2007) where isolated and vulnerable rural populations lost many planting seasons. It further threatens the indigenous knowledge systems upon which traditional farming depends, and this happens when farmers are summarily killed or incapacitated, for the farmers are the ones with the know-how about where, when and how to use local seed varieties. Sierra Leone being located in the geographic belt for the domestication of African rice *O. glaberrima*, a region where the genetic diversity of this species is high (Barry *et al.*, 2007) it is of high significance that farmers and farming systems in this region were threatened during the years of war. This presented a justifiable reason to conduct expedition missions post-war to rescue and conserve the remaining local varieties as we have done in this research.

9.5 Effect of war on rice genetic resources

The immediate effect of the war on on-farm rice resources was the massive loss of farmers seed stocks in all three districts studied, which was caused by disturbances in normal farming practices and the displacement of farmers. However, the severity of this loss was far lower than initially expected because most of the varieties were merely dispersed in different locations and could be recovered. The differences in number of samples collected per agro-ecosystem post-war demonstrated a shift in emphasis from upland to the lowland varieties, which was evident in all the districts. The results described in chapters 4 and 5 also demonstrated that farmers have more interest in varieties that mature earlier than those that were of longer duration. Farmer selection for the most suitable genotypes must have been intensified during the war years, making the eventual results a direct war effect. The most severe effect of the war was experienced in the Koinadugu district where farmers lost all the upland varieties due to the security situation. In addition to directly abandoning a number of upland rice types in the other two districts, the results show that farmers may have contributed to this also through variety selection practices.

However, the high interest in lowland short duration varieties could not be entirely attributed to the war. There is evidence that selection of suitable rice varieties for the lowlands has been in practice for a long time in the Kambia district (Carperter, 1978). Kandeh and Richards, (1996) mentioned poor soils, changing precipitation patterns, high labour demands for the uplands as reasons for changing cropping patterns in the district. Furthermore, there has been strong governmental support for increased food production, and in collaboration with the National Rice Research Station, the West Africa Rice Development Association, the IADPs and NGOs, government institutions have contributed to an increased emphasis on lowland cultivation in the years preceding the war (Dries, 1991; GOSL, 1953; RRS, 1989). The fact that lowland rice production is gaining prominence over the uplands could therefore be good news for the present government, which, like the governments before now, had promoted lowland agriculture using short duration varieties in the drive towards food security. In all of the cases presented here, the war could therefore be regarded as an accelerant for the increase in the process for selecting for lowland varieties, and not the determinant factor. The war in itself, though an unfortunate occurrence and gruesome as it was, presented an opportunity to the two main stakeholders that are concerned with rice biodiversity conservation and management in marginal environments in Sierra Leone. In the first place, it has created awareness amongst the farming communities about which component of the farming system is more resilient under security stress (i.e. the traditional seed system), and which is more vulnerable (the upland farming system); and to the research community, especially plant breeders, it indicated which plant traits are more important for sustaining varieties in widespread stress situations.

9.6 Rice variety responses to war stresses

The results described in chapter 5 demonstrated that though several rice varieties were lost as a consequence of the war, a good number of them did survive. The varieties that survived in large numbers demonstrated three main features: 1) wide pre-war dispersal, 2) phenotypic plasticity demonstrated in the ability to grow in both agro-ecosystems, and 3) the ability of the variety to exist in multiple sub-sets. *Yaka* was a typical representative of such a variety, demonstrating all three features, and was the highest in number amongst the surviving varieties. Other varieties demonstrated one or two of these features, which increased their chances of survival, leading to the assumption that more varieties might have avoided total disappearance if they had possessed these traits either in combination of two, or all at once. The significance of this finding is that plant breeders could include these genetic characteristics into varieties that are grown in potentially volatile regions of the world as a way of developing plant resilience that is supported by multiple adaptive capacities. This could help reduce the chances of plant genetic erosion under stress conditions.

9.7 Regional and agro-ecological effects on post-war rice genetic resources

The results describer in chapter 6 presented stronger differences between varieties at the ecosystem level than at the district level, which demonstrates that there is more discrimination for rice between the two ecosystems using quantitative and qualitative morphological traits than between the districts. It is obvious that farmer focus and emphasis on lowland varieties in the past two decades has led to the strong discrimination between the two ecosystems. This could only have resulted as a consequence of intensive farmer selection conducted over a long period of time. Barry *et al* (2006) observed that for rice growing cultures, the most important determinant of rice genetic diversity at the village level was its belonging to the two contrasted ecosystems, lowland or upland. The fact that this discrimination was strongly demonstrated in the post war varieties in Sierra Leone and not in the pre-war ones, demonstrates a shift in emphasis in the agricultural system in the country. It resulted both in obtaining more rice varieties for the lowland ecosystem and at the same time created discrimination between lowland and upland varieties. Some farmers related that they had re-adapted a number of upland varieties to the lowlands especially during the war years.

Because there were no strong differences for lowland varieties between the three districts studied, there is reason to believe that farmers' cultural practices for this ecosystem do not differ greatly. The advantage for this in the post-war circumstances is that lowland varieties from any of the districts could easily be introduced into the other districts. This finding is significant for seed rehabilitation agencies that would like to re-distribute lowland varieties from one region of the country to the other, and could especially be useful for replacing the lost lowland varieties in the Kono district with varieties introduced from the other districts.

Upland varieties on the other hand presented dissimilarities between the Kambia and Kono varieties, which signify differences in not only ecological conditions, but also the cultural practices of farmers for this ecosystem. Brush (1995) describes such relationship between on-farm genetic resources and farmer cultural aspects as "interwoven", depicting the manner in which farmers shape their varieties through different management practices. The implication for this for post-war seed rehabilitation in Sierra Leone is that not all upland varieties collected from one district could be adapted to the other districts.

9.8 Intra- and inter-variety variation between and within varieties

The accession of the rice varieties studied had a level of inter variety variation that could clearly distinguish one variety from the other at the genetic level (chapter 8). This finding agrees with that of (Portères, 1956) who observed heterogeneity of rice varieties in Guinea, and mentioned that even when varieties share a certain number of traits that support specific ecosystem adaptation and growth duration, they may differ with respect to a number of other traits. The farmers' practice of growing rice varieties in mixtures did not drastically affect the genetic composition of the individual varieties. However, the reasonably high level of intra-variety variation was attributed to this practice, as a the consequence of genetic exchanges between different varieties grown in mixtures (Miézan K and Ghesquière, 1986). It is important to realize that both phenomena of inter- and intra-variety variation form the strength of the farmers on-farm cultivation practices for rice, which makes them capable on the one hand to produce quality seed of specific varieties through selection made possible by inter-variety variation, while on the other hand to adapt these varieties to specific niches in stress-prone agro-ecologies by encouraging intra-variety variation. The relevance for this also lies in the consistency of farmers naming of varieties, which presents reliable indicators for genetic distinctiveness especially when the names concern traditional varieties. It underscores the fact that farmers are particular about the measure of the diversity of their rice genetic resources in any particular region, and this gives them continued drive to add to this diversity through the introduction of new genotypes. There is a generally held opinion that farmers usually have fewer opportunities for the introduction of exotic genotypes, and to speed up genetic recombination, especially when they are faced with new threats (Fris-Hansen and Sthapit, 2000). Traditional farmers therefore have to ensure their variety security through working for sustainable gene flow within their varieties, while at the same time variety entities are preserved.

9.9 General overview of rice genetic resources in Sierra Leone over a 30-year period

9.9.1 Genetic erosion

Genetic erosion of rice genetic resources was experienced at different levels in Sierra Leone, and as a result of various processes during the two periods studied in this research. The most direct evidence of genetic erosion was the total loss of upland rice varieties in the Koinadugu district. In addition to this, intensive selection processes by farmers in the search of suitable varieties (for either of the two ecosystems) do lead to the loss of vital genes and sometimes entire varieties (Brush, 1992). In-situ cultivation of the rice in the manner practiced in Sierra Leone also has the potential to accelerate changes in the crops population structure. Soleri and Cleveland (2004) attribute genetic erosion to the this practice which is often directed at selection for adaptive features. This indicated that the search for superior genotypes, especially during stress periods invariably leads farmers to intentionally discard “unwanted” varieties that may hold unique genetic material that could be useful for other future objectives (Boster, 1985; Brown, 2000).

9.9.2 Genetic shift

The differences that existed between pre-war and post-war rice varieties demonstrated the phenomenon known as genetic shift, which could be explained at two levels: 1) as a result of intensive farmer selection in the varieties that are continuously being grown; and 2) as an outcome of ex-situ conservation of a subset of the crop gene pool. Where farmer selection is continuously been practiced, a dynamic process is involved whereby farmers conduct variety selections non-randomly within growing crops on the field. Such selection practices are often directed towards a more defined morphotype, which, in our case, is determined by the two main agro-ecologies as described earlier. Genetic shift, in such a case, is associated with genetic erosion which occurs when varieties that express undesirable traits within crop populations are discarded (Crossa, 1989). On the other hand, ex-situ conservation is a static process wherein the dynamic process that goes on in rice planted in the field, sometimes even in mixtures, is almost completely halted. When this continues for several years, progressive natural and farmer selection in the field population could render the field materials different from the materials held in the gene bank (Wood and Lenne, 1997).

9.9.3 Genetic diversity

Despite the large losses observed in farmers’ seed stocks and at the variety level, together with the total loss of upland materials in the Koinadugu district, overall genetic diversity actually increased in the post war varieties, compared to pre-war ones (chapter 7). This finding presents the rather complex concepts of genetic erosion vs genetic diversity and how these relate to the loss of specific gene complexes when varieties disappear from farmers’ fields. For this argument, there may be reason to believe that genetic erosion in on-farm varieties does not necessarily result in the loss of genetic diversity in that particular crop. This notion supports the opinion of de Haan (2009) that genetic erosion in a broad sense seems unlikely to occur in diversity hotspots because most alleles are shared among farmers and across geographically separated cultivars. Stated differently, genetic erosion when referenced within the context of the loss of genetic diversity of cultivated crops in traditional farming systems is virtually non-existent except in the unlikely event that the entire crop species is wiped out. The stabilizing features of agro-biodiversity lies in the wide background of genetic material that is spread within and between cultivated species due to traditional cultivation practices. During times of stress, at the farm level this stabilizing factor becomes potentially important, enabling farmers to spread risk and increase the resilience to shock (CIAT, 2001). The stress factor also spurs farmers to seek for genetic resources from far afield, most likely from distant regions that have similar agro-ecological systems as theirs. The latter case was more evident with Kono farmers who not only had a collection of upland varieties that they obtained during the war, but also went in search of new varieties in the far south of the country which led to increased biodiversity for the upland eco-system.

The results of this research also revealed that combining pre-war and post-war varieties could result in a greater variation in the rice gene pool, suggesting that maximum diversity for rice in Sierra Leone can be restored if the germplasm stored in the WARDA collections were re-introduced into the Sierra Leone farming systems. This demonstrates that ex-situ genetic resources can be highly complementary to in-situ genetic diversity at the level of traditional cultivation systems. The differences in morphological traits of the two data sets used in this research may have resulted from the dynamic processes associated with farmer managed crops in-situ, including gene flow and farmer selection that had occurred in the 30-year period. There are also possibilities that the genetic differences expressed in crops phenotypic traits can strengthen each other wherein the genetic diversity embedded within the different varieties can restore greater diversity through complementary effects.

9.10 Seed relief options

Seed relief is discussed here from the standpoint of on-farm rice genetic resources, the restoration and replacement of specific varieties and the strengthening of farmers' seed security. The present research has shown that although varieties were lost as a consequence of the war, the losses (at the level of specific varieties) were not as severe as originally thought. Much of the varieties could be recovered and there is a reasonable diversity within the existing varieties that are available post-war. The most severe effect of loss was experienced at the farm level where a large number of farmers had lost their seed lots and are still struggling to recover them. This is the situation to date, even as this concluding chapter is written, May 2009, 6 years after the war (I was with the farmers in all three districts, just three weeks ago). The paradox is that there are government efforts to make seed available to farmers in large quantities, supported by huge donor funds and the intervention of local NGOs and CBOs. However, this effort is riddled with problems that are often associated with seed relief after disasters (Sperling, 1997): the relief depends on a limited number of varieties (in this case the government agency supplies only Nerica varieties); the varieties are often of poor quality and wrongly labeled (in terms of ecosystem adaptation), and the supplies are often made available too late for the planting season.

In order to restore effective and durable seed system performance in post-war Sierra Leone, the options for seed relief should be viewed within the framework of seed security that includes three components: seed availability, access to seed and seed quality aspects (Sperling and Cooper, 2003). This can easily be incorporated into the traditional seed systems, which still upholds the marginal agricultural systems for rice in the country. Unlike in countries that are more commercially oriented for cereals, modern varieties have not influenced the traditional systems for rice in Sierra Leone and research released varieties have not been an attractive option for farmers to completely replace their landraces. For this reason, seed system restoration should consider multiple varieties for a strong genetic resource base, which promote biodiversity and at the same time ensure farmers seed security. The findings of this research therefore should be incorporated into the three elements of seed security restoration for Sierra Leone as follows:

1. Seed availability: there is urgent need for seed system reform within the ministry of agriculture if the goal of seed availability is to be achieved. Instead of giving seed multiplication contracts to organizations who do not deliver quality seed, farmers themselves should be engaged with the responsibility, with financial and logistical support to multiply their own seeds. This will be more effective on a regional basis, especially for upland rice varieties as the presenr research shows. This would ensure that multiple varieties that are well adapted to both the cultural and ecological conditions are multiplied and made available to a large number of farmers.

2. Access to seed: seed security is understood by some authorities as access by farmers to adequate quantities of seeds of adapted crop varieties at all times (FAO, 1998). It is specific to farmers and farmer groups and should therefore encompass the various entities of the traditional seed system, including farmer exchanges and the local market schemes. Small-scale grain traders within local seed systems are known to provide a crucial seed channel for farmers (Longley, 1997). For Sierra Leone farmers, this will require the re-establishment and strengthening of the local seed system, instead of relying on the unidirectional flow of the government seed relief. The entire system can ensure a well defined access if this is built from the seed availability component mentioned in (1) above and this can be strengthened on a regional basis. The government and local district administration should also consider re-introducing the once vibrant and successful seed fairs.

3. Seed quality: Healthy seed systems need to maintain appropriate levels of seed quality, both physical and genetic, and farmers system often provide reasonable physical quality in farm-saved seed for cereals (McGuire, 2005). Often seed relief agencies are accused of delivering poor quality seeds, and farmers interviewed in this research agreed that most of the seeds they received from seed agencies were often of poor quality. Our results demonstrate that farmers are capable of maintaining high quality seeds, suggesting that quality aspects for seed security can be restored if farmers are in charge of their own seed systems, indeed with government support.

With a well-functioning traditional seed system in place, the recently rehabilitated Rice Research Station can take advantage of the situation and develop varieties that can easily fit into the farmers' production preference. Breeders will have the time to adopt the recommendations made in this research that includes developing varieties with genetic plasticity that promotes wide adaptability, for example. Plant breeding programs will also benefit from the reintroduction of pre-war rice genotypes that are kept in the gene banks at WARDA. McGuire (2005) argues that for breeders to be effective in working within farmers seed systems, there should be intensive collaboration between the breeders with distinct social groups of farmers, and working in the farmers own environment in order to produce more diverse varieties.

In conclusion, the availability, access to high quality genetic resources and maintenance of the biological diversity of rice is the most important substance of livelihood for rural communities in Sierra Leone. The only way to achieve this is through a secure and safe environment that guarantees normal livelihood processes, and the everyday practices and support systems of rural agriculture that is described in the earlier part of this thesis. This research has demonstrated that rice genetic resources have been resilient to some extent in surviving the war, but it is also vital to add that these resources have demonstrate only a fraction of the resilience of the farmers who have risked everything to save the seeds that we have recovered in the broken system. That is why this thesis is dedicated to those women and men, the farmers of Sierra Leone.

9.11 Recommendations:

From the outcomes of this research, the following recommendations for further research and installment of facilities can be drawn:

1. Research on rice should continue in Sierra Leone in order to answer more questions on its genetic resources distribution nationwide, the issues of genetic erosion - causes and consequences, and to further understand the genetic background of the crop at the farm level. Further research could booster options for genetic enhancement in the face of emerging threats such as of changing climatic, environmental and social conditions, which may offer possibilities for efficient rice germplasm conservation and documentation.

2. Regular expeditions should be conducted to collect rice genetic resources in the entire nation, also including wild populations. This should be followed by systematic characterization of the collected germplasm that will be vital for plant breeding and other variety improvement options for future use.

3. A core collection of rice genetic resources should be surveyed, collected and catalogued so as to maintain a representative set of accessions covering as much diversity as possible. Part of the collection could be stored in gene banks, for example in the present assessable black box agreement with the Center for Genetic Resources, the Netherlands where rice resources from Sierra Leone are held under long-term storage conditions. Field gene banks are also options, reducing short-term conservation costs, increasing management efficiency and maintaining accessibility to farmers in need of specific varieties.

4. Core researchable materials should be assembled, which will be a key to facilitate understanding, ease of identification and effective use of the genetic resources preserved on-farm. Research efforts are essential to evaluate the genetic potential in the materials, which will present the option to introduce new genes through a national rice improvement program.

5. More research should be conducted on a wide range of rice resources, especially at the molecular level in order to understand the nature of the genetic diversity nationwide. This will help, among other things, to identify duplicates and pursue options for the introduction of new accessions in order to increase potentially valuable diversity. Research should also focus on developing a genetic database and DNA fingerprinting in an attempt to facilitate rapid identification of genotypes with desirable traits for breeding options.

6. This research has also demonstrated the future direction rice farmers are taking: an increasing orientation towards the ecosystem perspective for the achievement of higher yields. It is therefore important to understand the various rice growing eco-systems, either collectively or, for more precision, at the niche and sub-system levels. For this purpose, technology development for variety management and improvement should encompass the diverse genetic potential in varieties that possesses both genetic and phenotypic plasticity in order to introduce these potentials into a larger gene pool.

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Summary

The research presented in this thesis tries to understand, though indirectly, the effect of the 10-year long civil war in Sierra Leone on rice genetic resources, using the effect of the war on farmers and their seeds as reference point. The chapters summarized below draw attention to the trend of events that outlined the purpose of the research – starting with the war and its consequences; the post-war composition of the genetic diversity of the rice crop, which is followed by a comparative assessment of the resources between pre-war and post-war situations. We also used the opportunity to understand both the phenotypic and genetic variation, as well as the ecosystem aspect of rice in the country.

The first chapter starts with the background information on the war and its devastating effect on all forms of production and development in the country. Agricultural production like all other sectors of the economy was severely affected. A FAO report supported these facts as follows: "… during the civil war, the agricultural extension services were handicapped by insecurity and lack of mobility and farmers were left virtually on their own. The farmers generally faced many production constraints, such as lack of seed, poor seed in terms of viability and variety mixtures for those who could get seed, lack of fertilizers, or high fertilizer prices and transportation cost, lack of machinery and hire services especially for land preparation for the swamp production areas." The chapter continues with the description of the geographical features and ethnic groups in the country, both of which define rice cultivation together with the general biodiversity status that were all threatened in one way or the other. Within this over all context, the problem that formed the core basis of the research was outlined, which eventually led to the research questions.

The second chapter presents a snapshot of Sierra Leone as it was before the war. It describes the farming systems and the major factors that shaped the rice genetic resources diversity between the years 1930 until 1990, part of the period described as pre-war. As long as the country was in a stable political and social-economic state, subsistence agriculture formed the major economic activity, and Sierra Leone was able to feed its people with the rice it produced. Because of this, Sierra Leone became the host country to the first and only national research station in Africa dedicated to rice alone. The resulting massive introduction of rice varieties from all over the world for research and crop development purposes led to the introduction of many new varieties to Sierra Leonean farmers. Sierra Leone thus became a reservoir of genetic diversity in rice. However, as the first chapter shows, the advent of the civil war threatened this stable utilization of the rice crop for more than ten years and this development eventually presented the motive for the current research.

Chapter 3 presents the methods employed to gather the needed information and obtain rice samples through field expeditions. While the methodologies applied followed the conventional approaches for farmer interviews and the collection of seed samples, the research was highly characterized by the prevailing security situation, which in turn highlighted concerns about the quality of the resulting data. It appeared that each of the target communities had just emerged from the heat of war and had grown distrust for both government officials and NGOs due to previous bad experiences. The chapter outlines the measures adopted to ensure security for the expedition team and to assure farmer confidence at the same time. It reports on the choice of personnel, the specialised training programs and, most importantly, the strategies that were devised to ensure the expedition teams' safety, and at the same time to obtain adequate samples of rice germplasm and passport data of reliable quality. The time of the expedition and use value of the information obtained was also crucial; rice germplasm was to be collected that had not been mixed with seeds coming from government rehabilitation efforts or NGO seed relief interventions.

The effect of the war on the human population and on farmers' effectiveness to cultivate and conserve their rice seed stocks is described in Chapter 4. Emphasis was placed on the farmers themselves, the disruption that occurred in their farming and seed systems, and their collective rice stocks rather than on individual rice varieties. Results indicated that the disruption to farming and seed systems and the options for farmers to grow rice under war conditions occurred at different levels in the three districts studied. Firstly, in the Kono district, the farmers were completely displaced from their homes to safer regions leading to an almost complete loss of their original rice materials, and to the acquisition of "new varieties" from the host region. Secondly, in the Koinadugu district farmers were dispersed and relocated within their own region instead of completely displaced. The overall effect of this relocation on rice cultivation was more drastic in the upland system, which was entirely abandoned during times of insecurity, resulting in a total loss of rice varieties for this ecosystem. Finally, in the Kambia district farmers actually stayed with one of the fighting forces when the region was occupied, which caused persistent insecurity in the region. The effect of this development on the management of rice genetic resources was minimal compared to the other two districts. However, the overall effect of the war on all three districts was that farmers lost considerable amounts of their seed stocks, although total losses of some rice varieties was averted because of the occurrence of all varieties in more than one village in the same region, including through initial variety dispersal or farmer movement during the war.

Chapter 5 deals with the effect of the war on individual rice varieties that can be regarded as the entities carrying the genetic diversity. In this chapter rice varieties are considered as genetic resources and their distribution should not be confused with the availability of seed stocks discussed in chapter 3 where farmer materials are considered in relation to the number of varieties individual farmers possessed. In other words, the number of rice varieties farmers jointly possessed as seed stocks does not add up to the total number of varieties in the region, since many varieties are found in various communities and with a number of farmers. There was little evidence that the war significantly altered the genetic composition of rice varieties, except for the upland varieties in the Koinadugu district. Where loss did occur, this was mostly affecting farmer seeds lots, as reported in chapter 3, and not so much the actual varieties. Moreover, most variety losses appeared to be only temporary, although farmers could not retrieve all of them. The majority of the varieties that were reported lost were actually "dispersed" in the regions, indicating good options for further recovery. The varieties that had the highest survival portrayed three characteristics: i) those that had a wider pre-war distribution, ii) showed plasticity in growing habits, and iii) existed in many different forms. As a result, farmers were able to sustain reasonable numbers of varieties and to recover those that they had lost through their traditional seed systems. It was concluded that for emergency seed relief programs to succeed in Sierra Leone, a thorough understanding of the sources of the dispersed varieties is vital.

In chapter 6 a closer look is taken at the rice genetic diversity using quantitative and qualitative data. The results indicate a clear distinction between upland and lowland varieties, which demonstrated the effectiveness of farmer selection with regard to the two production ecosystems. The analysis further demonstrated that some varieties had the potential to grow in both agro-ecosystems, and in different districts. It is important that plant breeders and conservationists understand such potential in both the development of new varieties, and the conservation of genetic resources for future use.

Chapter 7 presents evidence of a change in rice genetic resources between the pre-war and post-war situations. The loss of the entire upland variety gene pool in the Koinadugu district

demonstrated genetic erosion in this particular ecosystem. Although the number of varieties decreased for upland varieties in the other two districts as well, the genetic diversity actually increased for this ecosystem over the 30-year period as a result of variety introduction from other parts of the country. In contrast, the number of varieties increased for the lowland ecosystem, but genetic diversity decreased during the same period as a result of farmer selection. The chapter concludes with the suggestion that greater diversity in the national rice gene-pool could be achieved by the re-introduction of gene bank materials held at WARDA, which could be undertaken either through direct germplasm introduction to farmers or in the form of plant breeding programs.

The results of the AFLP study presented in chapter 8 indicate that rice varieties in Sierra Leone possess different levels of intra-variety variation, which makes it difficult to identify homogenous genotypes at the seed unit level. This was attributed to genetic exchanges caused by farmers' practices of growing different varieties in mixtures. However, this does not alter the genetic profile of inter-variety genetic differences between farmers' varieties which remains large enough to distinguish one variety from the other, and which demonstrates that the genetic composition of rice varieties is not drastically affected by the farmers' practice of planting in mixtures. For this reason, variety names in Sierra Leone are good indicators for genetic distinctiveness as far as these names concern traditional varieties, and provide a measure of the diversity of the rice genetic resource of a given region. The results also show that rice varieties do undergo genetic changes when they are cultivated under different cultural practices. This became apparent from the genetic differences measured between Sierra Leone and Guinea synonymous varieties.

Samenvatting

Het onderzoek gepresenteerd in dit proefschrift probeert het effect van de 10 jaar lange burgeroorlog in Sierra Leone op de genetische hulpbronnen van rijst te begrijpen, met het effect van de oorlog op de boeren en hun zaden als uitgangspunt. De hoofdstukken vestigen de aandacht op het verloop van de gebeurtenissen die aanleiding gaven tot het doel van het onderzoek – beginnend met de oorlog en de gevolgen daarvan, de samenstelling van de genetische diversiteit van het gewas rijst na de oorlog, gevolgd door een vergelijking van de voor- en na-oorlogse situatie. Ook werden de fenotypische en genetische variatie bestudeerd, zowel als de ecosysteem aspecten van rijst in het land.

Het eerste hoofdstuk begint met achtergrond informatie over de oorlog en het verwoestende effect ervan op alle vormen van productie en ontwikkeling in het land. De agrarische productie is ernstig beinvloed, net zoals alle andere sectoren. Een FAO rapport beschrijft deze feiten als volgt: "…tijdens de burgeroorlog werden de agrarische hulpdiensten belemmerd door de onveiligheid en mobiliteitsproblemen en werden de boeren aan zich zelf overgelaten. De boeren werden geconfronteerd met vele productie beperkingen, zoals het gebrek aan zaad, zaad van lage kwaliteit, in termen van kiemkracht en mengsels van rassen, voor hen die aan zaad konden komen, gebrek aan bemesting, of hoge prijzen voor meststoffen en het transport ervan, gebrek aan machines en huurkrachten, vooral voor het voorbereiden van akkers in de moerasgebieden." Het hoofdstuk vervolgt met de beschrijving van de geografische kenmerken en de ethnische groepen in het land, die beiden het verbouwen van rijst bepalen, samen met de algemene toestand van de biodiversiteit, die allemaal op een of andere wijze bedreigd werden. Binnen deze context werd het kernprobleem van het onderzoek in kaart gebracht, leidend tot het formuleren van de onderzoeksvragen.

Het tweede hoofdstuk geeft een moment opname van Sierra Leone zoals het was voor de oorlog. Het beschrijft het boerenbedrijf en de belangrijkste factoren die de diversiteit aan genetische hulpbronnen van rijst vorm gaven tussen 1930 en 1990, de voor-oorlogse periode. Zolang het land politiek en sociaal-economisch stabiel was, vormde landbouw de belangrijkste economische activiteit, en was Sierra Leone in staat zijn volk te voeden met rijst. Hierdoor werd Sierra Leone het land waar het eerste nationale onderzoeksinstituut in Africa werd gehuisvest, dat zich alleen aan rijst wijdde. De resulterende massale introductie van rijst rassen afkomstig uit de gehele wereld voor onderzoek en het ontwikkelen van het gewas, leidde tot het beschikbaar komen van vele nieuwe rassen voor de boeren van Sierra Leone. Sierra Leone werd op deze manier een reservoir van genetische diversiteit van rijst. Echter, zoals getoond in het eerste hoofdstuk, bedreigde de komst van de burgeroorlog dit stabiele gebruik van rijst gedurende meer dan 10 jaar, en deze ontwikkeling was de aanleiding van het onderhavige onderzoek.

Hoofdstuk 3 presenteert de gehanteerde methoden om de noodzakelijke informatie te verzamelen en om rijst monsters te verzamelen door middel van veld expedities. Terwijl de toegepaste methoden de conventionele benaderingen voor het interviewen van boeren en het verzamelen van zaad monsters volgen, probeerde dit onderzoek het effect van de oorlog op de boeren en hun rijst genetische hulpbronnen te bepalen in een situatie die gekenmerkt werd door onveiligheid waardoor er zorg ontstond over de kwaliteit van de resulterende gegevens. Het bleek dat elk van de benaderde gemeenschappen nog maar pas van het oorlogsgeweld bekomen was, en wantrouwig stond tegenover zowel vertegenwoordigers van de overheid als van niet-gouvermentale organisaties (NGO's) door recente slechte ervaringen. Het hoofdstuk beschrijft de maatregelen die genomen werden om de veiligheid van de expeditie te garanderen en tegelijkertijd de boeren gerust te stellen. Het beschrijft het selecteren van personeel, de gespecialiseerde trainigsprogramma's en, uiterst belangrijk, de strategieën die werden ontworpen om de veiligheid van het expeditie team te garanderen en tegelijkertijd geschikte rijst monsters en betrouwbare passport data te verkrijgen. Het tijdstip van de expeditie en de gebruikswaarde van de verkregen informatie waren ook van belang; het rijst materiaal moest worden verzameld voordat het vermengd werd met zaden afkomstig van de hulppogingen van de regering of NGO's.

Het effect van de oorlog op de menselijke populaties en op de mogelijkheden van de boeren om rijst te verbouwen en hun zaad voorraden te bewaren wordt beschreven in hoofdstuk 4. De nadruk lag op de boeren zelf, op de verstoring die optrad in hun landbouw- en zaad-systeem, en op hun gezamelijke rijstvoorraden, minder dan op individuele rijst rassen. De resultaten gaven aan dat de verstoring in hun landbouw- en zaad-systeem en de mogelijkheden van de boeren om rijst te verbouwen onder oorlogsomstandigheden, in de drie bestudeerde districten verschillend optraden. In het Kono district werden de boeren uit hun huizen verdreven naar andere, veiligere regio's en dit leidde tot een bijna compleet verlies van hun rijst materiaal, en tot het verkrijgen van nieuwe rassen in hun opvang regio. In het Koinadugu district werden de boeren verspreid en verplaatst binnen de eigen regio en niet geheel uit het district verdreven. Het effect van dit soort verplaatsing op de rijstbouw was drastischer in het 'upland' ecosysteem, dat geheel werd verlaten in onveilige perioden, resulterend in een volledig verlies van de rijst rassen in dit ecosysteem. In het Kambia district verbleven de boeren daadwerkelijk bij een van de strijdende partijen toen de regio werd bezet en de veiligheid continu werd beinvloed. Het effect van die situatie op het beheren van de genetische hulpbronnen van rijst was minimaal vergeleken met de twee nadere districten. Het totale effect van de oorlog op alle drie districten was dat de boeren aanzienlijke hoeveelheden van hun zaad voorraden verloren, hoewel het volledig verloren gaan van bepaalde rassen werd tegengegaan doordat de rassen in meerdere dorpen in dezelfde regio aanwezig waren, alsmede door het verspreiden van rassen en het zich verplaatsen van boeren tijdens de oorlog.

Hoofdstuk 5 behandelt het effect van de oorlog op individuele rijst rassen, de eenheden die de genetische diversiteit bevatten. In dit hoofdstuk worden rassen als genetische hulpbronnen beschouwd en hun verspreiding moet niet worden verward met de beschikbaarheid van zaad voorraden zoals besproken in hoofdstuk 3, waar het materiaal waarover boeren beschikken wordt beschouwd in relatie tot het aantal rassen dat een individuele boer bezit. Met andere woorden: het aantal rijst rassen dat boeren gezamenlijk bezitten als zaad voorraden, vormt samen niet het totale aantal rassen in de regio, omdat vele rassen in verscheidene gemeenschappen en bij meerdere boeren worden aangetroffen. Er was weinig bewijs voor dat de oorlog de genetische samenstelling van deze rijst rassen significant heeft beinvloed, behalve voor de upland rassen in het Koinadugu district. Waar er verlies optrad, beinvloedde dit meestal de zaad voorraden van de boeren, zoals besproken in hoofdstuk 3, en niet zo zeer de eigenlijke rassen. Bovendien bleek het verlies van een ras meestal slechts tijdelijk, hoewel de boeren ze niet allemaal konden terugkrijgen. De meerderheid van de rassen die als verloren golden, was in werkelijkheid verspreid in de regio's, waardoor er goede mogelijkhden waren voor herstel. De rassen met de hoogste overlevingskans hadden een brede voor-oorlogse verspreiding, vertoonden plasticiteit in hun groeiplaatsen en bestonden in vele verschillende vormen. Hierdoor waren de boeren in staat een redelijk aantal rassen in stand te houden en de verloren gegane weer terug te krijgen door hun traditionele zaad systeem. De conclusie werd getrokken dat om de nood steun programma's in Sierra Leone te laten slagen, een diepgaand begrip van de bronnen van de verspreide rassen essentieel is.

In hoofdstuk 6 wordt in detail gekeken naar de genetische diversiteit in rijst aan de hand van kwantitatieve en kwalitatieve gegevens. De resultaten wijzen op een duidelijk onderscheid tussen de upland and lowland rassen, een gevolg van de effectiviteit van de selectie door boeren ten aanzien van deze twee productie ecosystemen. De analyse maakte verder duidelijk dat bepaalde rassen in staat waren in beide agro-ecosystemen te groeien, en ook in de verschillende districten. Het is van belang dat veredelaars en natuurbeschermers deze mogelijkheid begrijpen, zowel voor het ontwikkelen van nieuwe rassen als voor het in stand houden van genetische hulpbronnen voor toekomstig gebruik.

Hoofdstuk 7 presenteert bewijzen voor een verandering in de genetische hulpbronnen van rijst tussen de voor- en na-oorlogse situatie. Het verlies van de totale upland gene pool in het Koinadugu district toont de genetische erosie in dit bijzondere ecosysteem. Hoewel het aantal upland rassen in de andere twee districten ook afnam, werd de genetische diversiteit in dit ecosysteem over een periode van 30 jaar zelfs groter als een gevolg van het introduceren van rassen vanuit andere delen van het land. In tegenstelling hiermee, nam het aantal lowland rassen toe maar de genetische diversiteit werd minder als gevolg van selectie door boeren. Het hoofdstuk besluit met de suggestie dat grotere diversiteit in de nationale rijst gene pool kan worden bereikt door het her-introduceren van genebank materiaal bewaard bij WARDA, hetgeen kan worden ondernomen of door directe introductie van dit materiaal bij de boeren, of door een veredelingsprogramma.

De resultaten van de AFLP studie gepresenteerd in hoofdstuk 8 geven aan dat de rijst rassen in Sierra Leone verschillende niveaus van binnen-ras variatie vertonen, waardoor het moeilijk is homogene genotypen in de zaadmonsters te indentificeren. Dit werd toegeschreven aan genetische uitwisseling veroorzaakt doordat boeren verschillende rassen in mengsels telen. Dit verandert echter het genetische profiel van de tussen-ras verschillen niet, die groot genoeg blijven om het ene ras van het andere te onderscheiden, hetgeen aantoont dat de genetische samenstelling van rijst rassen niet drastisch wordt beinvloed door de het planten van mengsels door de boeren. Hierdoor zijn ras benamingen in Sierra Leone goede indicatoren voor genetische verschillen voor wat betreft de traditionele rassen, en ze geven een maat van de diversiteit van de genetische hulpbronnen van rijst in een bepaalde regio. De resultaten tonen ook dat rijst rassen genetische veranderingen ondergaan wanneer ze onder verschillende cultuur omstandigheden verbouwd worden. Dit werd duidelijk uit de genetische verschillen die werden gemeten tussen rassen met dezelfde naam uit Sierra Leone en Guinea.

Appendix 1: Germplasm collecting data form

Germplasm Collecting Expedition 2003/2004

Date:…………………………………………….

Team Collector(s)……………………………………………….. **Collectors No**.:…………..

Farmers name:…………………**Village**………………………**District**……...…..……………

Crop type…..………………………………… **Crop (variety) name**:…………..…………….

Vernacular/Cultivar name……………………………...………

Meaning of vernacular name………………………………………………………………..

Locality:……………………………..………………………………………………………

Latitude:……………………. **Longitude**:……………………… **Altitude**:…………………**m**

Habitat:………………………………………………………………………………………

Ecology cultivated:	Swamp	upland	undulating upland	Hilly
Material:	Seed	panicle	fruit	whole plant
Sample:	Population	Individual	Random	Sorted
Status:	Cultivated	Weedy	Semi wild	Wild
Source:	Field	Market	Wild veg.	Garden

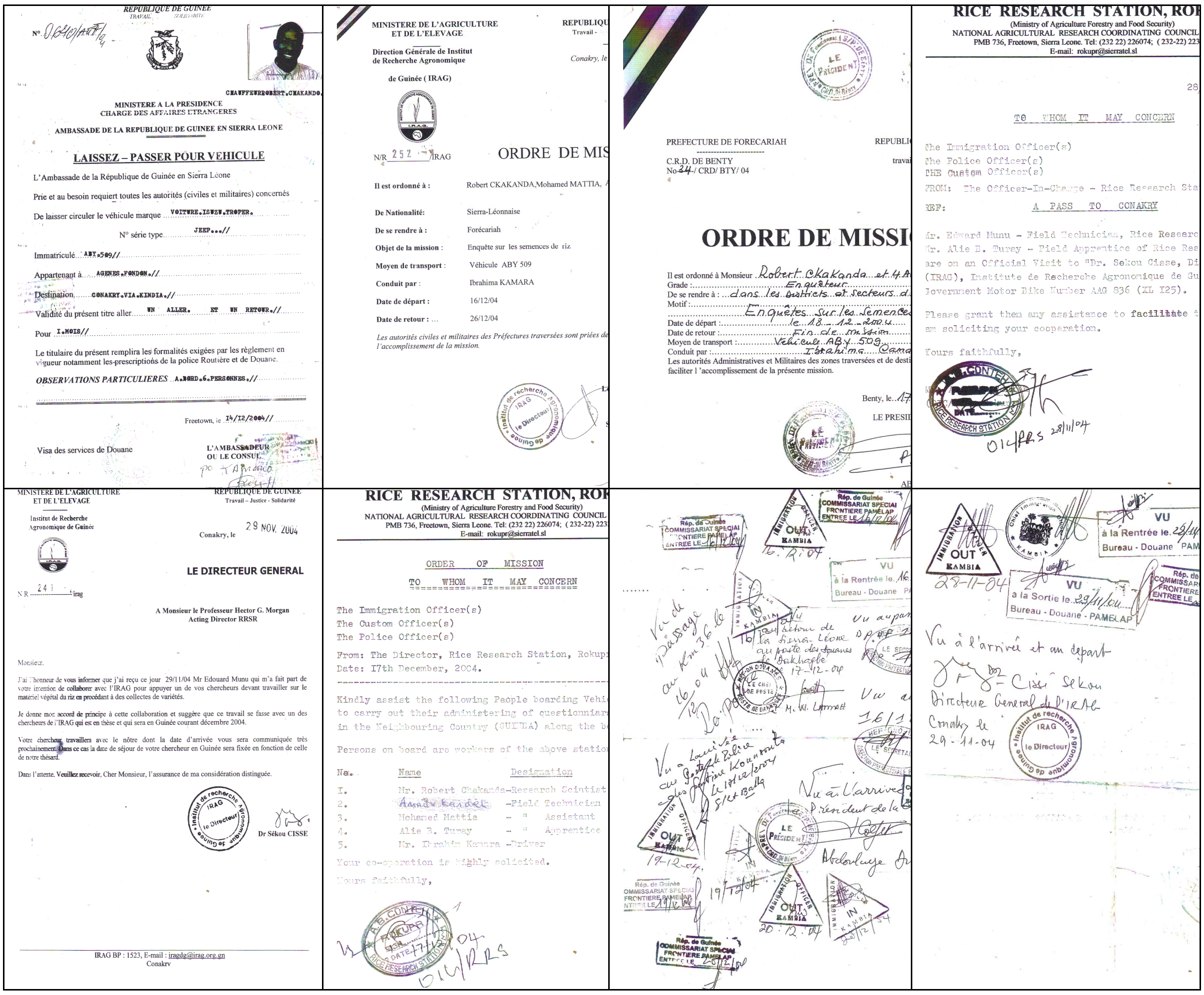
Farmer's seed source: ……………………..…………………………………………………….

When was seed obtained:…..…………………………..……………………………………………

If before the war, how was it maintained during the war?…………………………………………

Disease symptoms (if any)..……………………**Other features**:………………………………..

Appendix 2: Demonstration of security concerns: A cross section of authorization documents and stamps required for a single entry/person into neighboring Guinea from Sierra Leone during rice genetic resources collecting mission immediately after the Sierra Leone war. The number of stamps on the two pages in the lower right columns indicates the number of security checkpoints.


REPUBLIQUE DE GUINEE

MINISTERE A LA PRESIDENCE
CHARGE DES AFFAIRES ETRANGERES

AMBASSADE DE LA REPUBLIQUE DE GUINEE EN SIERRA LEONE

LAISSEZ – PASSER POUR VEHICULE

L'Ambassade de la République de Guinée en Sierra Leone

Prie et au besoin requiert toutes les autorités (civiles et militaires) concernés

De laisser circuler le véhicule marque VOITURE.ISUZU.TROPER.

N° série type JEEP...//

Immatriculé ABY.509//

Appartenant à AGENES.FONDON.//

Destination CONAKRY.VIA.KINDIA.//

Validité du présent titre aller UN ALLER. ET UN RETOUR.//

Pour 1.MOIS//

Le titulaire du présent remplira les formalités exigées par les règlement en vigueur notamment les prescriptions de la police Routière et de Douane.

OBSERVATIONS PARTICULIERES A.BORD.6.PERSONNES.//

Freetown, le 14/12/2004//

Visa des services de Douane

L'AMBASSADEUR
OU LE CONSUL

MINISTERE DE L'AGRICULTURE
ET DE L'ELEVAGE

Direction Générale de Institut de Recherche Agronomique de Guinée (IRAG)

N/R 252 /IRAG

ORDRE DE MIS

Il est ordonné à : Robert CKAKANDA,Mohamed MATTIA,

De Nationalité: Sierra-Léonnaise

De se rendre à : Forécariah

Objet de la mission : Enquête sur les semences de riz

Moyen de transport : Véhicule ABY 509

Conduit par : Ibrahima KAMARA

Date de départ : 16/12/04

Date de retour : 26/12/04

Les autorités civiles et militaires des Préfectures traversées sont priées de ... l'accomplissement de la mission.

PREFECTURE DE FORECARIAH

C.R.D. DE BENTY
No 34 / CRD/ BTY/ 04

ORDRE DE MISSIO

Il est ordonné à Monsieur Robert CKakanda et 4 ...

Grade : Enquêteur

De se rendre à : dans les Districts et secteurs d...

Motif : Enquêtes sur les semences

Date de départ : le 18-12-2004

Date de retour : Fin de mission

Moyen de transport : Véhicule ABY 509

Conduit par : Ibrahima Cama...

Les autorités Administratives et Militaires des zones traversées et de desti... faciliter l'accomplissement de la présente mission.

Benty, le 17...

LE PRESIDENT

RICE RESEARCH STATION, ROK
(Ministry of Agriculture Forestry and Food Security)
NATIONAL AGRICULTURAL RESEARCH COORDINATING COUNCIL
PMB 736, Freetown, Sierra Leone. Tel: (232 22) 226074; (232-22) 223...
E-mail: rokupr@sierratel.sl

TO WHOM IT MAY CONCERN

The Immigration Officer(s)
The Police Officer(s)
The Custom Officer(s)

FROM: The Officer-In-Charge – Rice Research Sta...

REF: A PASS TO CONAKRY

Mr. Edward Munu – Field Technician, Rice Researc...
Mr. Alie B. Turay – Field Apprentice of Rice Res...
are on an Official Visit to "Dr. Sekou Cisse, Di... (IRAG), Institute de Recherche Agronomique de Gu... Government Motor Bike Number AAG 836 (XL 125).

Please grant them any assistance to facilitate t... am soliciting your cooperation.

Yours faithfully,

28/11/04

014 RRS

MINISTERE DE L'AGRICULTURE
ET DE L'ELEVAGE

REPUBLIQUE DE GUINEE
Travail – Justice - Solidarité

Institut de Recherche Agronomique de Guinée

Conakry, le 29 NOV 2004

N.R. 241 /irag

LE DIRECTEUR GENERAL

A Monsieur le Professeur Hector G. Morgan
Acting Director RRSR

Monsieur,

J'ai l'honneur de vous informer que j'ai reçu ce jour 29/11/04 Mr Edouard Munu qui m'a fait part de votre intention de collaborer avec l'IRAG pour appuyer un de vos chercheurs devant travailler sur le matériel végétal du riz en procédant à des collectes de variétés.

Je donne mon accord de principe à cette collaboration et suggère que ce travail se fasse avec un des chercheurs de l'IRAG qui est en thèse et qui sera en Guinée courant décembre 2004.

Votre chercheur travaillera avec le nôtre dont la date d'arrivée vous sera communiquée très prochainement. Dans ce cas la date de séjour de votre chercheur en Guinée sera fixée en fonction de celle de notre thésard.

Dans l'attente, Veuillez recevoir, Cher Monsieur, l'assurance de ma considération distinguée.

Dr Sékou CISSE

IRAG BP : 1523, E-mail : iragdg@irag.org.gn
Conakry

RICE RESEARCH STATION, ROK
(Ministry of Agriculture Forestry and Food Security)
NATIONAL AGRICULTURAL RESEARCH COORDINATING COUNCIL
PMB 736, Freetown, Sierra Leone. Tel: (232 22) 226074; (232-22) 223...
E-mail: rokupr@sierratel.sl

ORDER OF MISSION

TO WHOM IT MAY CONCERN

The Immigration Officer(s)
The Custom Officer(s)
The Police Officer(s)

From: The Director, Rice Research Station, Rokup...
Date: 17th December, 2004.

Kindly assist the following People boarding Vehi... to carry out their administering of questionnair... in the Neighbouring Country (GUINEA) along the b...

Persons on board are workers of the above statio...

No.	Name	Designation
1.	Mr. Robert Ckakanda	Research Scientist
2.	Aarafie Kargbo	Field Technician
3.	Mohamed Mattia	" Assistant
4.	Alie B. Turay	" Apprentice
5.	Mr. Ibrahim Kamara	Driver

Your co-operation is highly solicited.

Yours faithfully,

17.12.04

014 RRS

Appendix 3. Qualitative morphological traits and the methods of measurement

No.	Trait	Abbreviation	Method of measurement
1	Seedling vigor	sdvg	1 = Low 2 = medium 3 = High
2	Culm strength	clmst	1 = strong 3 = moderately strong 5 = intermediate 7 = weak 9 = very weak
3	Leaf pubescence	lfpub	1 = glabrous 2 = intermediate 3 = pubescent
4	Flag leaf angle	flan	1 = erect 3 = intermediate 5 = horizontal 7 = descending
5	Panicle compactness	pancp	1 = Compact 5 = intermediate 9 = Open
6	Secondary branching	secbr	1 = absent 2 = light 3 = heavy 4 = clustering
7	Panicle exertion (near maturity)	pnexe	1 = less than 90% 2 = 90 – 95% 3 = 100%
8	Shattering	shat	1 = very low 3 = low (1-5%) 5 = moderate (6 – 25%) 7 = high (>50%)
9	Awning	awns	0 = none 1 = short 5 = long
10	Seed coat pubescence	sdct	1 = Glabrous 2 = Short Hairs 3 = Long Hairs (Velvety)
11	Endosperm type	endtp	1 = non glutinouse (non waxy) 2 = glutinous (waxy) 3 = intermediate
12	Aroma	aroma	0 = none 1 = lightly scented 3 = aromatic

Appendix 4. Quantitative morphological traits and the methods of measurement.

No.	Trait	Abbreviation	Method of measurement
1	Number of days to germination	germ.	number of days from sowing
2	Germination percentage	germ%	percentage of seeds that germinated 7 days after sowing
3	Seedling height	sdl.ht	cm; soil level to the tip of flag leas 2 weeks after sowing
4	Plant height	pt.ht	cm; soil level to the tip of flag leaf at maturity
5	Culm length	cul.lth	cm; soil level to the base of the base of the lowest leaf on the stam
6	Number of days to 50% flowering	50.fw.	number of days from sowing to the day 50% of plants flower
7	Number of days to maturity	mat	number of days from sowing to the day 50% of plants are at physiological maturity stage
8	Number fo tillers	#tillers	number of tillers counted at reproductive stage
9	Number of productive tillers	#prd.til.	number of tillers with panicle counted at reproductive stage
10	Leaf width (flag leaf after heading)	lf.wdth.	cm; average of 5 flag leaves measured across the widest part at reproductive stage
11	Leaf length(flag leaf after heading)	Lf.lth.	cm; average of 5 flag leaves measured from leaf base to tip at reproductive stage
12	Ligule length	lig.lth	mm; average of the length of the ligules of 5 plants
13	Panicle length	pan.lth	cm; length of panicle measured from base to tip of 5 plants
14	Grain Weight (100)	gr.wgth	g; 100 grains weighed
15	Grain length	gr.lth	mm; average length of 5 grains
16	Grain width	gr.wth	mm; average of the width 5 grains

Curriculum Vitae

Robert Chakanda was born on the 25th July 1964 in Tefeya, Kono District, Sierra Leone. He attended the Catholic Primary School in his home town and later pursued secondary education at the Sewafe Secondary School in the same District. In 1985 Robert enrolled at the Njala University College, University of Sierra Leone and graduated in 1989 with a Bachelors degree, major in Biological Sciences and minor in Chemistry. Upon graduation, he joined an international research team at the West African Rice Development Association (WARDA) conducting research on mangrove rice, and after two years he was employed at the Rice Research Station in Rokupr, Sierra Leone working on the sorghum crop.

In 1994, Robert enrolled for an M.Sc at the Botany Department, Fourah Bay College, University of Sierra Leone, completed course work but had to terminate the program at the final stages because of the war in the country. He proceeded to the Netherlands on a fellowship program at the Wageningen University (WU) where he graduated in 2000 with a M.Sc. in Plant Breeding, specialization Crop Sciences. In 2001 he started working at the Center for Genetic Resources, the Netherlands as researcher on Agricultural Biodiversity and Farming Systems. He further pursued another study at the Geographic Information Science (GIS) department, graduating in 2003 with another M.Sc in GIS, specialization Imaging Spectrometry and Crop Modeling.

Robert continued to work at the CGN when he joined the Biosystematics Group of the WU in 2003 for a PhD research, specialization Plant Genetic Resources, and for this study, the rice crop. Robert is widely travelled in Africa and is involved in a number of agricultural research projects. He has strong interests for research in Africa, and during his work at CGN, and the course of his PhD program, he has conducted several research and consultancy assignments on that continent.

Education Statement of the Graduate School Experimental Plant Sciences

Issued to: Robert Chakanda
Date: 15 September 2009
Group: Laboratory of Biosystematics, Wageningen University

1) Start-up phase	*date*
► **First presentation of your project**	
Study of Genetic Resource in Post-war Sierra Leone - Proposal and plan of action	Jun 2003
► **Writing or rewriting a project proposal**	
Study of Genetic Resources in Post-war Sierra Leone	Aug-Nov 2003
► **Writing a review or book chapter**	
War and Genetic Resources - The Sierra Leone Chapter	2007
► **MSc courses**	
► **Laboratory use of isotopes**	
Subtotal Start-up Phase	*13.5 credits**

2) Scientific Exposure	
► **EPS PhD student days**	
EPS PhD student day, Radboud University Nijmegen	*Date*
EPS PhD student day, Wageningen University	
EPS PhD student day, Wageningen University	Jun 02, 2005
► **EPS theme symposia**	Sep 19, 2006
EPS theme 4 Genome plasticity symposium 2006, Radboud University, Nijmegen	Sep 13, 2007
► **NWO Lunteren days and other National Platforms**	
► **Seminars (series), workshops and symposia**	Dec 08, 2006
Symposium Current Themes in Ecology: 'CT6 Experimental Evolution'	
Symposium Current themes in Ecology 7	
Symposium Current themes in Ecology 8	Apr 02, 2004
► **Seminar plus**	Nov 19, 2004
► **International symposia and congresses**	Apr 29, 2005
XVII International Botanical Congress, Vienna (Austria)	
5th International symposium on taxonomy of cultivated plants, Wageningen.	
Conference of parties 9 (COP9), Bonn, Germany	Jul 17-23, 2005
Climate change effect on Agriculture and PGR, Ouagadougou, Burkina Faso	Oct 15-19, 2007
► **Presentations**	Mar 19-30,
Oral presentation, 30th Nordic-Baltic postgraduate course in Plant Breeding, Norway	2008
Plant Research International - Oral presentation of expedition results	Oct 26-31, 2008
Poster presentation, Research Group, Rice Research Station, Freetown, Sierra Leone	
Poster Presentation, PhD students day 2005, Radboud University, Nijmegen	Jun 17, 2004
Oral presentation, 'Molecular Phylogenesis: Reconstruction and Interpretation'	Sep 2004
IBC Vienna, Poster presentation	Feb 2005
Plant Research International - Oral presentation of preliminary analysis of results	Jun 02, 2005
Poster presentation, Research Group, Farmers Technical Conference, Freetown.	Oct 17-21, 2005
Oral presentation, Climate change effect on Agriculture PGR, Ouagadougou.	Jul 17-23, 2005
► **IAB interview**	May 2006
► **Excursions**	Jul 14 2006
	Oct 29, 2008
Subtotal Scientific Exposure	*16.1 credits**

3) In-Depth Studies	*date*
► **EPS courses or other PhD courses**	
30th Nordic-Baltic Postgraduate Course in Plant Breeding, Rauland (Norway)	Jun 12-18, 2004
PhD course 'Molecular Phylogenesis: reconstruction and Interpretation'	Oct 17-21, 2005
► **Individual research training**	
Study visit to Centre of Ecology and Hydrology, Monk's Wood (UK)	Nov 08, 2004
Subtotal In-Depth Studies	*3.9 credits**

4) Personal development	*date*
► **Skill training courses**	
Scientific Writing	Sep 2003
Project planning and Time management	Sep-Oct 2004
► **Organisation of PhD students day, course or conference**	
► **Membership of Board, Committee or PhD council**	
Subtotal Personal Development	*3.3 credits**
TOTAL NUMBER OF CREDIT POINTS*	**36.8**

Herewith the Graduate School declares that the PhD candidate has complied with the educational requirements set by the Educational Committee of EPS which comprises of a minimum total of 30 credits

** A credit represents a normative study load of 28 hours of study*

The research described in this thesis was financially supported by the following: the PhD sandwich program, Wageningen University; the Center for Genetic Resources, Netherlands (CGN); the Biosystematics Grop, Wageningen University and the Nederlandse Organisatie voor Wetenschappelijk Onderzoek (NWO).

Cover design: Robert Chakanda and Jo-Ann Snel
Thesis layout: Robert Chakanda and Jo-Ann Snel

Printers: Wöhrmann Print Service, Zutphen, the Netherlands