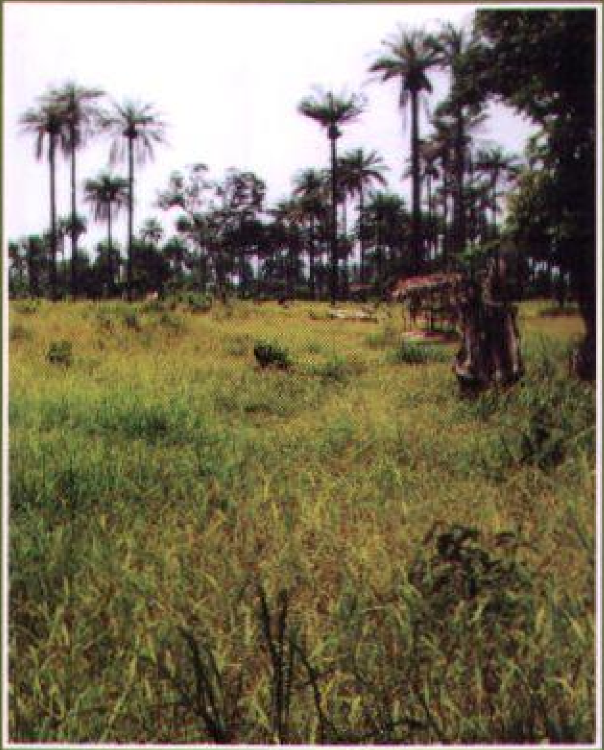
FARMER MANAGEMENT OF GENE FLOW



The impact of gender and breeding system on genetic diversity and crop improvement in The Gambia

EDWIN NUIJTEN

Propositions

1. The more a crop has a cross-pollinating nature, the less likely new varieties develop in the field *(this thesis)*.

2. The farmer millet seed system can be considered low-cost and robust, whereas the farmer rice seed system is more of a high maintenance and less robust system, needing constant exchange and testing of off-types to keep it adaptable *(this thesis)*.

3. More research attention should be given to improving conventional formal crop development.

4. It is important to view agriculture not as a linear development but rather as a complex resultant of local and global ecological, cultural, social and economic factors.

5. Luck is a factor impossible to incorporate in models.

6. The term hunter-gatherer results from an idealised view of prehistoric society, whereas the term gatherer-hunter describes the role of man in prehistoric times more accurately.

7. A domang domang, a mang kori kuu le (Mandinka proverb meaning that if you do things step by step, you will succeed in anything). Nevertheless, sometimes a big leap is needed for progress.

8. Both proponents and opponents of GMOs base their arguments on the emotions hope and fear.

Propositions belonging to the PhD thesis of Edwin Nuijten
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Farmer management of gene flow

The impact of gender and breeding system on genetic diversity and crop improvement in The Gambia

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Acknowledgements

Finally, the last part of the thesis (although it is at the beginning). You are about to read a thesis which is the hybrid product of natural and social sciences. This shows in the combination of many tables and figures with a lengthy text. One implication may be that, through integrating natural and social sciences, certain sections may lack a bit of in-depth information of a certain discipline. However, another implication may be that certain sections are too technical or too sociological for other readers. I have tried maintaining a balance. Ideally, I would have also liked to write about other issues linked to farmer management of gene flow, but it was necessary to draw a line somewhere. I decided to stay closely to the main research questions.

Although it is often said that a PhD is a long and lonely adventure, I hardly experienced any lonely moments. This is probably because of the many people who helped me, particularly during the fieldwork. Another reason is that this thesis is not a project on itself, but has its roots in my last MSc thesis for which I did fieldwork in Kwazulu Natal in South Africa. Hence, I was extremely happy when I heard that the proposal submitted to NWO-WOTRO was approved. I thank NWO-WOTRO for funding this research.

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1 Introduction

1.1 The rationale behind this thesis

Over the past decades, researchers tried to answer the question how to improve agriculture in low-input, marginal, diverse environments and to alleviate poverty. Whereas in areas with favourable conditions farmers more readily adopted the green revolution package of formal varieties, fertiliser and irrigation, in less favourable areas farmers have been more reluctant to adopt such packages. Common reasons given are that the varieties are not adapted to farmers' conditions and that fertiliser is too expensive. This thesis investigates how farmers actually choose and manage varieties in less favourable areas.

The idea for this research was born in 1999, amid debate about Participatory Crop Improvement (PCI) or whether genetically engineered seeds might offer hope to low-resource farmers. A suggested use of genetic engineering would be to develop apomixis to maintain the genetic quality of varieties. This would enable a one time distribution of formal[1] varieties to farmers who could maintain genetic quality simply when multiplying seed. In the case of variable environments farmers might be presented a range of formal varieties, from which they would be free to choose the varieties best suited to their conditions. But this raises the question what might happen if and when circumstances changed, e.g. when rainfall patterns or disease pressures shifted? Would breeding institutes be able to offer rapid instant replacements for the varieties no longer suited to local conditions? And how fast would such new varieties reach farmers in remote places? PCI seems to offer a different approach to this problem of remoteness. Could farmers manage some aspects of variety improvement themselves? In the past, they must have had ways of coping with changed conditions. But how exactly did they cope? Was it through having a large variety portfolio, constant replacement or exchange of varieties, seed selection, or the development of new varieties based on selecting from among spontaneous crosses? Further questions arose about what might have happened to these activities in recent years. Did farmers continue to maintain genetic diversity, to keep future options open, or was adaptation a 'random' process with farmers exerting an unconscious selection? The benefits of PCI were advocated, triggering the question what exactly farmer variety development offered and whether it was possible to integrate farmer variety development and formal variety development into a well-designed policy for farmer-assisted science-guided crop development?[2]

To answer basic questions about farmer selection practices a multidisciplinary approach has been adopted. This thesis combines information from field trials, field observations, participant observation and interviews. The study explores the phenomenon of farmer selection in two crops, with two plant breeding systems, and takes systematic account of gender and the multiple interactions arising. The result is an account which tries to place these multiple interactions (some treated in more detail than others) in a systematic context, in which genetic diversity, adaptation and gene flow are viewed in relation to socio-economic factors, farmer variety portfolio management, seed exchange, variety exchange, variety naming, seed selection, variety selection, farmer variety development and pollen flow between varieties and between cultivated

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[1] In this thesis modern (improved) varieties are called 'formal varieties' because I will also discuss 'new' farmer varieties which may be confused with 'modern varieties'

[2] When these questions were raised, we did not know that it had actually been tried in the past to transfer apomixis, through conventional techniques, from distantly related wild relatives to cultivated pearl millet (*Pennisetum glaucum*) (see Renno *et al.*, 1997). That this thesis is partly about pearl millet is a co-incidence.

and wild relatives. For some of these aspects various hypotheses have been formulated by earlier researchers, but never actually researched in detail. Furthermore, it was particularly common in the past that sociologists would study and write about the social aspects of farming communities and agronomists would study the more technical aspects without bringing the two areas fully together. The fact that the word 'agriculture' embraces the word 'culture' suggests that sociology and agronomy are indeed inseparable. So the present thesis attempts to offer data and analysis interesting to both sociologists and agronomists, involved in research on farmer seed systems, Participatory Crop Improvement, *in-situ* conservation and formal crop development.

The fieldwork site is in the West African country of The Gambia. Although The Gambia is small and seemingly unimportant in terms of economy, it has an interesting situation, on the transition between the savanna and the tropical forest zone and offering a range of distinctive farming systems. The Gambia river basin is according to Portères (1962) part of a secondary centre of origin for African rice (*Oryza glaberrima*) Both rice and millet - studied in this thesis - have probably been cultivated in the river basin for more than 3000 years. This gives the thesis some potential relevance not only to anthropologists, but also to archaeologists, since what it reports concerning seed selection and management may give clues to scenarios for early domestication. Earlier generations of farmers were confronted with unpredictable weather conditions, illness and other disasters. As today, they had to decide which portion of a ripening field to reserve as seed for sowing, how to recover seed after a bad harvest, and which and how many varieties to grow. As in the past, management of genetic diversity is still an important aspect of ensuring stable yields.

Before turning to the research questions and methodology of this study, an overview is given of seed systems, crop development and participatory crop improvement.

1.2 Formal and informal seed systems

Seed systems in low-input and high-input agricultural systems are organised in different ways. In high-input agricultural systems found, for example, in Europe, North America and certain parts of Asia, farmers rely on breeding companies and agricultural research institutes (the so-called formal seed sector) for seed and new formal varieties. In many low-input farming systems, found mostly in tropical countries, farmers often save their own seed or borrow from or trade with other farmers (the so-called informal seed sector, sometimes also called the farmer seed system or traditional seed system) instead of buying from the formal sector. The above picture is schematic. Reality is more complex. In most, if not all, high-input and low-input farming systems farmers rely on both the formal seed sector and the informal seed sector, although often in varying ratios. Furthermore, low-input farming systems rely on a variety of other sources and channels for seed and new varieties. These include family relationships, friendship networks, trade routes and labour migration. The more people travel, particularly over greater distances, the more new types are imported and tried out (Zeven, 1998). That farmer seed systems are very important, dynamic and in many instances efficient is increasingly recognised (Bellon, 2001). At the same time it is recognised that in several countries in West Africa the formal seed sector tends to be underdeveloped and simply cannot serve all farmers (Richards, 1986).

In high-input agricultural systems the formal seed sector forms a separate entity, but in low-input agricultural systems informal seed systems are part of and entangled with farming systems. To understand how informal seed systems work also requires understanding of how farming systems work. It is tempting to define a village, a region or a particular ecology as a farming system, but farmers have family ties, and trade and labour relations, beyond their village, region or ecology, through which knowledge, technologies and seeds flow. Therefore, a farming system, and consequently a farmer seed system, is a very complex, loose open system. Moreover, there are no fixed rules for seed exchange between farmers, and each transaction is influenced by the relationship of the two parties, their social positions and the degree of confidence between them (Seboka and Deressa, 2000; Badstue et al., 2002). Because contacts between farmers in these systems can vary from year to year, it can also be argued that it is more appropriate to use the term network instead of system (see Seboka and Deressa, 2000). Many features of such networks, such as diversity or local adaptation, are the result of both individual and collective activities, not all of which are planned (McGuire, 2005).

Because informal seed systems are complex open systems they are influenced by a wide range of socio-economic as well as biological and ecological factors. In farming communities seed suppliers are often the better-resourced households (Wright et al., 1994; Dennis, 1988). Farmers cultivating smaller fields more often sell or eat their seed than farmers able to cultivate bigger fields (Almekinders et al., 1994; Sperling and Loevinsohn, 1993). In some communities this might result in patron-client relations which ultimately lead to the perpetuation of poverty of particular actors within communities (Wright et al., 1994). However, under certain circumstances, possibly less strenuous conditions, such patron-client relations may offer a kind of insurance (Richards, 1990). Dennis (1988) argues that in Thailand there is no particular group of farmers clearly more interested in variety management than others but that wealthier farmers tend to be experiment more with varieties. In Rwanda, the local bean experts and innovators identified by the community were often poorer farmers (Sperling, 1992; Sperling et al., 1993). Further, it seems that a personal interest or pleasure in seed and seed management is another aspect (Prain, 1994). This might help explain why some farmers in Rwanda did not distribute any seed to others, while a small number of farmers (6% of the total) were responsible for almost half of all seed distributions (Sperling and Loevinsohn, 1993).

Farmer variety portfolios

Most seed companies prefer to deal in limited numbers of crop varieties (Wright *et al.*, 1994). Almost all, if not all, seed systems studied in low-input areas show evidence of farmers using a wide range of varieties: i.e. maize in Mexico (Louette *et al.*, 1997; Bellon, 1996), potato in the Peruvian Andes (Zimmerer, 1998; Quiros *et al.*, 1990; Brush, 1995), sorghum in Ethiopia (Teshome *et al.*, 1997; McGuire, 2005), rice in Thailand (Dennis, 1988) and Sierra Leone (Richards, 1986), cassava in Peru (Boster, 1985) and beans in Central Africa and Malawi (Voss, 1992; Sperling *et al.*, 1993, Martin and Adams, 1987). Most of these crops have been studied in their so-called 'centres of diversity', a notion used to explain the large numbers of crop varieties that are found. But also in Malawi and other parts of Central Africa farmers grow mixtures of beans consisting of large numbers of genotypes (Voss 1992, Sperling *et al.* 1993, Martin and Adams, 1987) even though these countries do not belong to the centre of origin of beans. Voss (1992) claims that the large number of bean varieties in these mixtures is maintained by careful farmer selection, and if left to natural selection the varietal mixtures would consist of fewer varieties.

The common reasons farmers cite for using so many varieties are to prevent total crop failure, to match different varieties to different ecological conditions and to meet a range of uses. Ecological conditions comprise a range of factors: soil quality, temperature and rainfall regime, topography, etc (Bellon, 1996). Use purposes include culinary, cultural and market preferences regarding taste, colour, size, cooking time and processing quality (Almekinders *et al.*, 1994). Other use criteria in particular areas are beer-brewing quality and fodder quality. In areas where formal varieties are available, farmers often use the local varieties for consumption and for cultural or religious purposes. Genetic diversity is also maintained to keep future options open, as an insurance against changing environmental and socio-economic conditions (Dennis, 1988; Almekinders *et al.*, 1995). The number of varieties grown by farmers is also related to the available labour (Zimmerer, 1991), or to minimise labour bottlenecks (Richards, 1986). Other factors determining the number of varieties used are the importance of a crop and the time it has been in a farming system.

Whereas it was once thought that farmers preserve a static portfolio of crops and crop varieties, a more common view in recent literature is that farmers import and discard diversity in a dynamic fashion, according to needs at any given period (Cromwell and Van Oosterhout, 1999). Hence, the range of crops and crop varieties, both farmer and formal varieties, might be broadened or narrowed according to the economic, socio-cultural and environmental circumstances of the individual farmers (Cromwell and Van Oosterhout, 1999).

Cultural importance determines how carefully people look at plants and animals (Boster, 1985). In sharp contrast to the large diversity that can be found in potato fields in the Peruvian Andes (Zimmerer, 1998), farmers in Kwazulu Natal in South Africa grow only one variety of potato (Nuijten, unpublished). In Kwazulu Natal potato is a relatively new and uncommon crop (but gradually gaining in importance). In areas where a particular crop is indigenous, variety usage is wider and includes use of particular crop types in rituals to reinforce prestige or to forge social ties (Bellon, 1996).

Another factor that plays a role in variety and seed management is gender; in many farming systems women know more about and are more active in variety management (Howard, 2003). Women are particularly involved in seed selection (Almekinders *et al.*, 1994). In many cultures in Southern Africa crops belong to the women's domain, while livestock belongs to the men's domain. In Peru however, where cassava is the principle food crop for the Amuesha, the (male) shaman plays a key role in maintaining and breeding cassava varieties, even though it is a women's crop (Salick *et al.*, 1997). The reason that the shaman plays such an important role is that cassava is central to Amuesha religion. It is believed that before world began, cassava plants were people, and at the end of the world, cassava will be people again. This is good of instance of the role that culture and belief plays in shaping variety management.

1.3 Crop development

In various high-input systems in tropical countries, particularly in South-East Asia, formal varieties have been successfully adopted and to a large extent have replaced farmer varieties. In low-input systems, farmers predominantly use their own traditional varieties, even though a wide range of formal varieties has been developed and is available. Farmers are very keen on new varieties but very often adopt formal varieties only to a certain level. The common argument for farmers not adopting formal varieties is that these varieties do not suit farmers' agro-ecological, socio-economic and cultural needs (Almekinders *et al.*, 1994; Sperling and Loevinsohn, 1993; Cromwell *et al.*, 1993).

Farmers improve and develop varieties (Almekinders and Elings, 2001). Therefore, crop development can be differentiated into two systems: A formal and an informal system, which can also be called *institutional breeding* and *farmer breeding* respectively (Amanor *et al.*, 1993). Farmer breeding and institutional breeding activities are shaped by different aims and objectives and, as outlined by Berg (1993), deploy different breeding technologies and strategies (Table 1.1).

Table 1.1: Differences between scientific (formal) and traditional breeding (Berg, 1993).

Plant breeding activity		Scientific breeding	Traditional breeding
Breeding technology	genetic resource base	world resources	local resources
	crossings	controlled	random
	selection method	efficient	moderately efficient
Breeding strategy	adaptation	broad adaptation	specific adaptation
	variation	uniform varieties	heterogeneous varieties

In this section, various aspects of scientific and farmer breeding are compared, following Berg (1993) who looked at the following aspects: genetic resource base, crossing of materials, selection methods and the effects of breeding strategies on adaptation and variation. It should be emphasised that formal and informal breeding are not separate entities, but rather that they complement each other and that interaction between both systems takes place (Hardon and De Boef, 1993). It is mainly for the sake of analysis that they are treated as separate entities. But an underlying motivation to learn more about the farmer breeding system is the possibility that it could become more systematic and efficient, especially if provided with appropriate institutional support. This is an ambition behind the present study.

Genetic resource base

Whereas breeders have access to world-wide genetic resources, farmer breeding depends on locally available material. It is often claimed that breeding programs use limited amounts of elite materials, which eventually leads to a narrowing of gene pools (Chang, 2003; Rasmusson and Philips, 1997; Harlan, 1975; Voss, 1992). Smale (1997) argues that scientific breeding has not led to the narrowing of gene pools, but that statements about the narrowing of gene pools are rather the result of scientific intuition. Furthermore, it can be argued that breeders have access to world wide genetic resources (Smith, 2000). Farmer breeding might be much more successful if it had similar rights of access (Seboka, forthcoming). The rice variety IR 64 is the result of the recombination of 20 varieties (Dalrymple, 1986). Closer examination of the breeding schedule of IR 64, presented by Dalrymple (1986), however, shows that of those 20 varieties, four varieties together contributed more than 60% to its genetic background (assuming equal contribution of each parent per generation).

So, even though breeders have access to world-wide genetic resources they often use a limited set of materials. The main argument why breeders use only elite materials is that this is the most effective and fastest way to increase yields of new varieties. The risk of using a narrow gene pool is that, as favourable alleles are selected and fixed, genetic variability is reduced, thus presumably reducing the potential for future progress (Rasmusson and Philips, 1997). To ensure future progress it seems logical to infuse continuously new genetic diversity into breeding programs. However, breeding programs often show no reduction in selection advances after many cycles of selection. For example, Dudley *et al.* (1974) show that after 70 cycles of selection on oil and protein content in a narrow maize population, considerable progress was still possible. Berg (1993) argues that, since in this experiment the frequency of high protein alleles increased from 0.37 in the original population to 0.62 after 48 generations, selection had not resulted in fixation or loss of alleles and that the theoretical limit of selection has not yet been reached. The common theory to explain this continuous progress is the continuous recombination and accumulation of favourable alleles acting in additive or epistatic ways

(Rasmusson and Philips, 1997; Witcombe, 1999). So, with present knowledge, it is very difficult to know whether and when the limits for the generation of new genetic variation within breeding programs based on narrow gene pools might be reached.

The effect of farmer breeding on long term genetic diversity is even less well understood. It might well be that two contrasting processes occur. One process is in which farmer varieties become genetically very uniform because of continuous selection on qualitative traits in the same gene pool (Cox and Wood, 1999) and because new farmer varieties are derived through genetic recombination of existing farmer varieties (Wood and Lenné, 1997). A contrasting process has been proposed, in which genetic diversity in the 'local gene pool' is maintained through mutation, introgression from wild and weedy relatives, hybridisation between varieties and the introduction of new landraces or formal varieties (Almekinders *et al.*, 1994). Little is known about the relative occurrence of these two processes. It is hard to find a basis in present levels of knowledge about plant population genetic resource distributions over the longer term for adjudicating between scientific and farmer breeding. The case for developing complementarity between the two systems is probably better based on practical considerations concerning access to planting material.

Efficiency of crossings

The difference between formal and informal breeding in relation to the creation of new genetic variation is quite straightforward. The crossing of different materials by breeders is controlled and very efficient, while crossings in farmers' fields are random (Berg, 1993). Because farmers often plant mixtures of varieties in the same field, or because they plant different varieties adjacently, spontaneous hybridisation occurs and new genotypes develop. How widespread is the selection of such genotypes is not very clear (Berg *et al.*, 1991). There are only a few examples of farmers consciously mixing different varieties or species in the same field to stimulate cross-pollination, which comes nearest to directional crossing. In certain areas of Indonesia, farmers mix rice varieties with the aim to stimulate hybridisation (Hardon, personal communication). In a few cases farmers purposefully stimulate hybridisation of wild and cultivated species. In particular areas in Mexico farmers promote hybridisation between wild relatives with cultivated maize (Wilkes, 1977; Benz *et al.*, 1990). In parts of Sierra Leone, farmers grow Asian and African rice in the same field because of agronomic advantages and cultural beliefs and may thus unintentionally stimulate hybridisation between the two species (Longley and Richards, 1993; Longley, 2000). In areas where cultivated and wild species grow sympatrically, through hybridisation, new genotypes with potentially useful characteristics can evolve (Harlan, 1975; Nabhan, 1985; Jarvis and Hodgkin, 1999). However, the extent and significance of hybridisation between cultivated and wild species is uncertain (Jarvis and Hodgkin, 1999; Wood and Lenné, 1997). Hybridisation may occur, which is impossible or very difficult to detect.

It is also documented that farmers are sometimes keen to develop off-types they find in their fields into varieties (Richards, 1985). Development of new varieties in farmers' fields is nevertheless a random process. It also happens that farmers find new varieties growing on the crown of a palm tree or germinating in elephant dung (Richards, 1986), growing in a hedge (Zeven, 1998), or dropped by birds (Gamble, 1955).

Selection methods

Apart from selection of off-type plants, which are then developed into new varieties, farmer selection also entails mass-selection (both positive and negative). Harlan (1975) was one of the first who argued along these lines. In the first part of the 20th century the common view was that farmers do not consciously apply seed selection. Zeven (1998) sums up definitions of landraces given by nine scientists over the period 1909-1952. The definitions differ from each other, but the common view was that landraces are genetically diverse and become adapted through selection pressures exerted by the environment and farmers' cultivation methods (Zeven, 1998). Through their farming practices, farmers selected for big seeds, disease resistance, tall plants and lateness, while nature would select against types that were too tall and too late as too tall varieties would lodge and those that mature too late would result in immature, shrivelled seeds (Zeven, 1998).

In 1975, Harlan adds that farmers also consciously select for traits like larger heads, larger seeds, more seeds, better seed-set, more determinate growth, easier threshing. Furthermore, through selection, varieties differ in seed colour, flavour, texture and storage quality (Harlan, 1975). It is not clear, however, how important farmer selection is compared to natural selection. It has been shown that natural selection on barley can lead to yield increases of 2-3% per generation (Allard, 1988). In the early 1990s, it became a more common view that landraces develop as conjoint product of both natural and artificial (conscious human) selection (see Berg *et al.*, 1991). Nowadays, the idea is widespread that the interactions between people, the environment, and their crops result in a wide range of crops and a large diversity within crops (Amanor *et al.*, 1993). Furthermore, these interactions also resulted in a human capacity to further develop crops through a process of continuous adaptation, experimentation and development of new varieties (Amanor *et al.*, 1993; Bellon, 1996). In the formal seed system these processes of genetic development have been largely eliminated through the selection of uniform varieties and a strict seed quality control system, combined with high seed replacement rates at farm level (Almekinders *et al.*, 1994).

<u>Efficiency of farmer and breeder selection within plant populations</u>

Selection by farmers can be considered less efficient than selection by breeders (Berg, 1993). But hardly any hard data are available. In fact, Soleri *et al.* (1999) showed that farmers can achieve S-values (Selection differential = difference between population selected in and selected population) in maize similar to what breeders achieve. However, the effects of farmer selection were not statistically significant, which was contributed to high levels of intra field variation (Soleri *et al.*, 2000). This then might explain why, after thousands of years of farmer selection, there are still high levels of genetic diversity within farmer maize varieties. Other factors affecting farmers' selection efficiency are their views about the importance of seed selection, whether they have time or are willing to take time for seed selection, and the efficiency with which knowledge is transmitted to next generations (Berg, 1993). So the effectiveness of farmer selection remains in doubt. Also, there is a great difference between knowledge and practice (Voss, 1992). Although most farmers know how to manage and select seed, conflicting labour demands often prevent the ideal practice.

However, the rate of efficiency of breeders is also not that much clear. Some have wondered why selection programs result in yield increases of at most a few percent (Simmonds, 1989). Particularly if these percentages are in the same order of magnitude found for yield increases based on natural selection (see Allard, 1988). One of the reasons is that, although yield is the most important selection criterion, the highest yielders are not always the best varieties because they are poor in other characteristics. Simmonds (1989) points out that the main factor is that the selection efficiency is too low. In most breeding programs selection starts in the F2 with unreplicated plots, while from the F2 - F4 most of the heterosis is not yet fixed. So, ideally, selection should start at earliest in F4, but because of the large numbers involved this is generally viewed as practically impossible. Simmonds (1989) suggests that selecting the best genotypes in these early stages should be considered as much an art as a science. Theoretically, there is still scope for improvement in scientific selection.

Selection between populations and varieties

In terms of the ability to select the best materials among a wide range of lines or populations there appears to be little difference between farmers and breeders, although they often choose different materials. Ceccarelli *et al.* (2001) showed that the barley populations farmers select are different from those that breeders select, and that farmer selections are better adapted to farmers' conditions. In Rwanda, Sperling *et al.* (1993) showed that the bean varieties chosen by farmers yield higher under farmer conditions, but are often different from the varieties selected by breeders. This indicates that farmers often know quite precisely which materials do well under their conditions. It has been shown in various studies that plant features prioritised by breeders and farmers are different (Wright *et al.*, 1994; Jusu, 1999; Almekinders and Elings, 2001). For farmers, yield stability is more important while breeders emphasise yield potential. Furthermore, farmers often consider traits like taste, storability or fodder quality to be essential, whereas breeders often do not pay these traits much attention. Farmers select and develop varieties that are adapted to a range of environmental and cultural niches (Teshome *et al.*, 1999). On the other hand, breeders often pay more attention to disease resistances. Farmers are unable to select for such traits, particularly if they are cryptic, such as polygenic disease resistance (Wood and Lenné, 1997). More often, however, breeders aim at monogenic disease resistance (Hardon and De Boef, 1993) which is more easily broken down by plant diseases (particularly by sexually propagated diseases).

Plant breeding has focused a good deal on desirable shoot characteristics, while little attention has been given to root characteristics (Smith and Zobel, 1991). Since the latter are difficult for farmers to assess and often correlate with drought tolerance and efficiency in water use (factors likely to increase in importance in future), it would be a good basis for farmer complementarity if breeders paid more attention to root development.

Breeding strategies

Through the use of external inputs like fertilisers, irrigation and pesticides, modern agriculture tries to adapt the environment to crops and varieties, which tend, in turn, to be very uniform (Amanor *et al.*, 1993; Almekinders and Elings, 2001). Hardon and De Boef (1993) argue that formal breeding, as developed in Europe and North America, is well adapted to temperate, benign environments, but is less adapted to less favourable marginal farming environments, common in many tropical countries. Another difference is the focus on crops. Formal breeding has mainly focused on the major food and cash crops and the most common environments, while farmer breeding does not have a particular focus, nor on environment nor on crops (Hardon and De Boef, 1993).

Breeders often think that breeding is done most economically in monoculture, because of the greater ease, simplicity and control of environmental variation possible in monocultures (Smith and Zobel, 1991). Furthermore, breeders usually consider adaptation only from an economic perspective, i.e., whether a variety can give economic production under certain conditions (Ceccarelli, 1997). Formal varieties are often hybrid varieties or single line varieties, selected for their high-yielding capacity in a wide range of environments under optimum conditions. One reason why potential benefits of G × E interactions (increasing overall production by matching genotypes and environments) have been neglected is that experimental approaches to understand and manipulate G × E interactions have not been available previously (Smith and Zobel, 1991). Furthermore, the uniformity of varieties is a requirement stimulated by regulations of formal seed supply systems and plant breeders' rights (Hardon and De Boef, 1993).

In informal seed systems, uniformity requirements for varieties are less strict than in formal seed systems. The general view is that landraces, or farmer varieties, tend to be genetically and morphologically very diverse (Zeven, 1998). That this is not always the case will be shown later. Local crop development is a continuous and dynamic process of maintenance and adaptation of crops and varieties to the environment and to specific local household or cultural needs (Hardon and De Boef, 1993; Richards, 1985; Teshome *et al*, 1999). It is also argued that through this continuous process of adaptation farmer varieties become adapted to very specific conditions (Berg *et al.*, 1991; Cleveland *et al.*, 1994; Busso *et al.*, 2000). There are, however, no hard data on this, and it is not clear whether it really occurs, and whether it is under farmer control (Wood and Lenné, 1997). The opposite might also be possible, i.e. that varieties degrade in farmers' fields (Wood and Lenné, 1997; Worede and Mekbib, 1993). An alternative explanation is that environmental conditions (for example pests and diseases) may change so fast that varieties under farmer management are not able to adapt quickly and thus seem to degrade. They may in fact still be good varieties, but no longer appropriate to changed conditions.

1.4 Participatory crop improvement

From the 1980s onwards, awareness slowly grew that for formal crop development to be more successful in low-input systems the approach needed to be altered. Several researchers thought it would be better to have farmers participating in crop development and therefore set about acquiring a better understanding of what farmers really need (Maurya *et al.*, 1988; Haugerud and Collinson, 1990; Eyzaguirre, 1992; Sperling and Loevinsohn, 1993; Hardon and De Boef, 1993; Weltzien *et al.*, 1996; Witcombe *et al.*, 1996). The aim was a better-focused scientific breeding approach. But for breeders and farmers to work together effectively, in a functionally efficient division of labour, the comparative advantages of breeders and farmers needed to be better defined (Hardon, 1995).

This led to the development of so-called participatory breeding. Many different participatory methodologies have been developed which are often very different but are all called Participatory Plant Breeding (Sperling *et al.*, 2001). Over time, experiments in which farmers select between varieties have become known as Participatory Varietal Selection (PVS). Where the question was addressed whether farmers could also participate in the selection of segregating materials the approach tended to be termed Participatory Plant Breeding (PPB). To avoid confusion, the definitions and abbreviations as given by Almekinders and Elings (2001) will be used in this thesis. This means that Participatory Crop Improvement (PCI) is the general term for all participatory crop improvement methodologies, PVS refers to selection between varieties and elite materials, while PPB refers to selection in segregating materials. The aim of both PVS and PPB is to meet farmers needs better, to increase farmer researcher co-operation, to increase production in quantitative and qualitative ways, to enhance biodiversity and germplasm conservation and to reduce development costs (Sperling *et al.*, 2001).

PVS

Setting up PVS-trials for potential varieties in farmers' fields led to greater interaction between breeders and farmers, and breeders came to understand better what farmers need. Via PVS, potential formal varieties can be identified much faster and a greater number are eventually adopted by farmers (Sperling *et al.*, 1993; Almekinders and Elings, 2001). One of the criticisms of PVS-trials was whether farmers were actually able to select the best materials in trials with large numbers of potential varieties. This criticism was refuted in several studies clearly showing farmers were able to work with large numbers of varieties (Sperling *et al.*, 1993; Ceccarelli *et al.*, 2001; Gridley *et al.*, 2002). However, individual farmers cannot be expected to set up such large trials on their fields without help from researchers (Witcombe and Virk, 2001).

It has been argued by some plant scientists that local selection may be effective in managing genotype × environment interactions, and that selection in marginal environments may uncover useful genetic potential neglected in formal breeding schemes (Ceccarelli, 1997; Simmonds, 1991). Sperling *et al.* (1993) point out that farmers not only judge materials differently from breeders, but farmers themselves vary in how they make judgements due to various socio-economic and cultural factors (including gender). This implies that the formula Genotype × Environment interaction (G × E) should be rewritten as G × E × S, in which S stands for the socio-economic environment and E for the ecological environment. PVS not only solves to some extent the G × E issue, but also the genotype × farmer interaction. For matching varieties to the ecological and socio-economic environment, it is expected that the number of varieties grown by farmers will increase, in that way increasing genetic diversity. Stimulating farmer selection may also serve genetic resource conservation by keeping local landrace materials "in play" (sometimes outcrossing with introduced materials). The role of the breeder in such circumstances is to make useful new genetic variation available for farmers to choose from (Weltzien *et al.*, 1996). It is argued that this may be a good way of reaching and benefiting neglected client groups.

PPB

Shortly after the first successes of PVS the question was raised whether farmers could also be involved in the selection of still segregating breeding materials in PPB (Almekinders and Elings, 2001). PPB can follow from the successful participatory identification of cultivars or be used where PVS is not possible or has failed (Witcombe and Joshi, 1996). PPB can be divided into two approaches. The first is one in which new genetic variation is taken to farmers' fields and farmers become involved in the development of new varieties out of this genetic variation. The second approach to PPB focuses on the collaborative improvement of established farmer varieties.

Compared to PVS, the first approach to PPB might be a more direct way of developing varieties that meet farmers' needs, by addressing G × E interactions. A by-product would be an increase in genetic diversity. However, setting up PPB based on traditional pedigree selection, with many small plots and lots of organisation, would require an increased commitment from research personnel and costs may limit the feasibility of this approach in many developing countries with poor research facilities (Sperling *et al.*, 1993). So for PPB to be workable in farmers' fields it is important to select a small number of crosses that produce large populations for both in- and outbreeding crops (Witcombe and Virk, 2001). Successful examples of this approach are the development of upland rice varieties in farmers' fields in eastern India (Virk *et al.*, 2002) and in Nepal (Sthapit *et al.*, 1996; Joshi *et al.*, 2001) and of beans in Colombia

(Kornegay *et al.*, 1996). A disadvantage is that under extreme conditions (like drought) seed might be lost, disrupting the whole development process. Another possible complicating factor is that sufficient progress must be realised to maintain farmers' enthusiasm and willingness to invest time and resources (Almekinders and Elings, 2001).

The second approach to PPB mostly applies to cross-pollinating crops and has been tried in several studies with maize (Soleri *et al.*, 2000; Smith *et al.*, 2001; Rice *et al.*, 1998), but not with other crops. Although best suited to cross-pollinating crops, it might also be possible with heterogeneous landraces of self-pollinators. Rice *et al.* (1998) point out genetic gains might not be realised, given high rates of seed replacement due to seed loss. Smith *et al.* (2001) show selection by farmers can in some cases have success, but that most farmers stopped their participation because they changed or lost their seed. Soleri *et al.* (2000) show selection gains on the basis of farmer selection are not significant, although farmer seed selection shows a clear selection differential. According to Soleri *et al.* (2000) selection in farmers' fields is likely to have little effect because of high levels of within-field variation. Other factors possibly explaining the small effects of farmer selection in existing populations are a low level of genetic diversity within a population for the trait selected for during many generations and high levels of plasticity directly or indirectly influencing morphological diversity for the selected trait. As is shown by Dudley *et al.* (1974) selection effects might vary widely from one generation to the other. Selection methods also might make a difference. In Soleri's study, farmers' own selection methods were used, whereas Smith's study used scientific selection methods on traits that were not selected for by farmers, possibly exploiting some genetic diversity hitherto untouched by farmers.

1.5 Research questions and thesis objective

The maintenance of a certain degree of variation within and between varieties is considered to provide harvest security and yield stability (Hardon and De Boef, 1993). Furthermore, local conservation, improvement and selection of genetic material are maintained by the interest of keen farmers in experimentation (Richards, 1985). It has also been stated that gene flow plays a crucial role in the development and maintenance of landraces. It is suggested that varieties continuously interact with each other, with weedy relatives and with their agro-ecological and socio-economic environment (Almekinders *et al.*, 1994; Nabhan, 1987). But little measured evidence has been offered on the actual gene flow processes at work in farmers' fields. Not that much is known about farmers' roles in maintaining or managing gene flow in their fields. Perhaps the underlying genetic variation is an "unknown" resource at risk of being accidentally eliminated by changes in circumstances (e.g. loss of weedy relatives through better weed control, or termination of gene-flow opportunities through changes in land-use configuration). It may be hypothesised that unless farmers know about gene flow and manage it, or maintain it through agronomic practices (even where it remains a "concealed" resource) then local selection will eventually "run out of steam" due to problems arising from too narrow a genetic base. So it seems important to build up a more precise and detailed picture of the processes at work, in order to identify both opportunities to maintain and enhance farmer selection practices, but also to protect against the unwitting elimination of local processes of value in maintaining genetic diversity.

The central question, then, is to explore how much, if at all, gene flow is under farmer management and regulated by agricultural practices and /or socio-cultural understandings. Are farmers aware of gene flow, and if so, how do they understand it, and have they adapted their farming system to maintain it? Since in The Gambia the genders specialise in different crops, an opportunity arises to see what difference gender makes in the local management and understanding of gene flow for crops with different breeding systems. It has often been suggested that women are more aware of and careful with genetic variation. The Gambian case allows this suggestion to be more fully explored and contextualised. Which farmer practices are most important for the regulation of this gene flow? What actual influence does management of gene flow have for the resilience and adaptability of the low-input farming system? Alternatively, if there is no discernible management of gene flow, what implications would such a finding have for continued emphasis on farmer selection and participatory plant improvement in conditions of rapid agronomic change and crop innovation?

This leads us to three main questions addressed by the research described below:

1. How is gene flow managed by farmers and which factors play a crucial role?
2. What is the impact of gene flow on the adaptability and resilience of the farming system?
3. Based on the answers to questions 1 and 2, what suggestions can be made to integrate formal and informal crop improvement?

Thus the objective of this study is to get a better understanding of local gene flow and its effects on crop genetic diversity (i.e. availability, genetic make-up and diversity of varieties) and as such on the farming system as a whole, and whether these effects are related to or influenced by breeding system, gender, farmer selection, or possibly other agricultural practices, socio-economic factors or cultural understandings, consciously or tacitly.

Obviously, the importance of gene flow can only be assessed after having first answered the question how farmers manage gene-flow. Secondly, to be able to understand the relative importance of gene flow it is important to understand other factors that play a role in keeping the farming system adaptable. The approach in this study is to fit all processes related directly or indirectly to gene flow into a single comprehensive, descriptive and explanatory picture, even at the expense of some sketchiness in detail. Additionally certain key parts of the picture are supported with 'hard' data from field trials. The overall picture generates more specific hypotheses about the importance and impact of gene flow on the farming system, some of which are answered and some of which are left for future work.

1.6 Research methodology

Theoretical framework

It can be considered that adaptation is related to gene flow at two levels: at field level and at farming system level. Adaptation at field level is related to pollen flow, while adaptation at farming system level is related to seed exchange. In low-input farming systems gene flow can be considered a function of pollen flow and seed exchange, which, in different ways, are influenced by natural and human selection pressures.

So, gene flow can be translated into the following formula:

Total gene flow = (seed exchange + pollen flow) * selection pressure

Pollen flow occurs predominantly between varieties of cultivated species, but pollen flow is also possible between cultivated and wild species. Seed exchange occurs because farmers need to replenish their seed stock and because they look for better varieties. In Chapter 6 a distinction will be made between seed and variety exchange. It is assumed that selection pressure interacts in different ways with seed exchange and pollen flow. Selection pressure can be both human (artificial) and environmental in nature. Farmers' practices also exert a selection pressure, and because of their unconscious nature, can be considered closer to environmental selection pressure than to human selection pressure. Seed exchange, pollen flow and selection pressure are influenced by and can be divided into the following factors.

Seed exchange (within and between villages) is directly influenced by:
- trade
- cultural practices and relations
- infrastructure
- bad harvests

Pollen flow is directly influenced by:
- breeding system of the crop (rate of cross pollination)
- synchronicity of flowering
- distance between the plots (related to weather conditions: wind force, wind direction, temperature, obstacles)
- mixtures in the field
- presence of wild and weedy relatives and volunteers

Selection pressure can be divided into:
- environmental conditions (climate, soil conditions, prevalence of pests and diseases)
- agricultural practices
- socio-economic conditions
- farmers' selection methods
- farmers' knowledge and understanding of gene flow

In Chapter 12, an attempt is made to elaborate this formula based on the information collected in this research. The formula allows the separate analysis of components that make up the total gene flow through a range of specific research questions:
- Which factors contribute most to pollen flow and seed exchange, thereby affecting gene flow as a whole?
- Which kind of selection pressures affect pollen flow and seed exchange most and in what ways?
- Are these selection pressures static or dynamic over the years?
- How does the whole of this gene-flow affect the genetic make-up of varieties?

The research attempts to establish certain basic data about gene flow processes in rice and millet under local management to help refine the questions above. In effect these data are used to model gene flow for rice and millet under local management in such a way as to test hypotheses (in farmers' fields) about the importance and sensitivity of various biological and cultural variables.

Choice of research sites and crops

Why The Gambia as a research site?

Western Africa is known to be the region of origin for some important food crops and an area of high genetic diversity for a number of other crops. The principal cereals traditionally cultivated in The Gambia are rice (originally *Oryza glaberrima*, but now mainly *O. sativa*), sorghum (*Sorghum bicolor*), pearl millet (*Pennisetum glaucum*) and fonio (*Digitaria exilis*) (Carney, 1989). Other important indigenous crops include yams (*Dioscorea* sp.) bambara groundnut (*Voandzeia subterranea*) and many types of beans (*Vigna* sp.).

The Gambia river is an axis of one of Portères' (1962) two secondary "cradles" of rice genetic resources in West Africa. African rice (*Oryza glaberrima*) is reported to have been grown for more than 3500 years and Asian rice (*O. sativa*) was probably introduced during the period of Atlantic contact from the 15th century (Portères, 1962). Pearl millet was domesticated about 4,000 to 5,000 years ago along the southern margins of the central highlands of the Sahara in West Africa (Brunken, 1977). In The Gambia no wild millet can be found, but semi-wild (weedy) millet is present in every millet field. For both crops hybridization and introgression still continue to take place between the cultivated plants and the wild or semi-wild species giving rise to new forms both of the crop and the weed (Purseglove, 1985; Second, 1982).

The Gambia river constitutes one of western Africa's ecological, social and cultural frontiers (Brooks, 1993). Since approximately the 12th century the Gambia river has been coextensive with the 1,000 mm rainfall isohyet, or 'tsetse fly line', demarcating the savanna and savanna-woodland zones in which cattle can be grazed only with difficulty. Furthermore, The Gambia has been relatively well studied from an ethnographic and agro-ecological point of view.

Why rice and millet?

One of the reasons to choose rice and millet is that both crops are important indigenous subsistence crops which have been grown in the region for thousands of years. Furthermore, for rice, wild and weedy relatives grow both within and outside the fields. For millet, no wild relatives can be found in The Gambia, but weedy relatives can be found in every field. Rice is a typical inbreeding crop, with a level of cross-pollination ranging between 0 and 1% (Grist, 1986; Purseglove, 1985), and millet a typical outbreeding crop, with a level of cross-pollination between 70 and 80% (Burton, 1974; Rao *et al.*, 1949).

Through the commercialisation of groundnuts (*Arachis hypogaea*) in the early 19th century, Gambian agriculture became more gendered and rice cultivation became non-commoditised (Watts, 1993). Whereas before 1850, both men and women where involved in rice cultivation, although with greater participation by women than by men, after 1850 rice cultivation became the sole responsibility of women (Watts, 1993). Groundnut and millet cultivation became solely the responsibility of men. Technical innovations, such as changes in crop repertoire, can often be seen as a vehicle for, and a consequence of, attempts by different groups within a community to exert control over the production process (Guyer, 1984; Whitehead, 1985).

Hence, because rice is cultivated by women and millet cultivated by men, a comparison of rice and millet seed systems is somewhat complicated by aspects of social competition and change. On the other hand, the strict gender separation in crop cultivation also allows a comparison of the knowledge of men and women on gene-flow. Furthermore, because within the region (Casamance, Sierra Leone, Mali) men of the same or similar ethnicities grow rice in broadly comparable conditions to women in The Gambia a comparison of research results with accounts in literature (e.g. Richards, 1986) allows a comparison between men and women on seed management of rice.

The comparison of these two crops enables evaluation of the importance of different aspects of gene-flow. How important are seed exchange and cross-pollination, are there differences in crop x weedy relatives interaction and how do cultivation practices relate to gene-flow? Do farmers apply different farming practices tot he two crops and do men and women have different ideas about variety development? In what ways does the knowledge of women and men differ regarding the breeding system of the two crops? Comparing two crops also provides good opportunities to discuss these issues with farmers.

Consequently the research investigates two sets of variables:

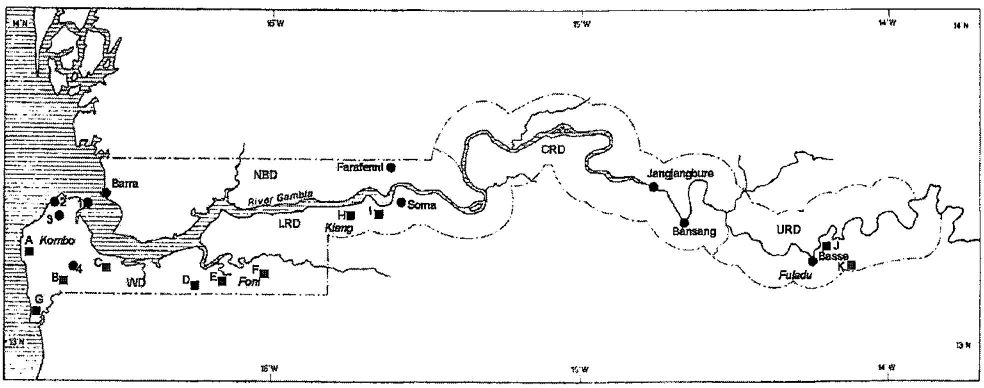
- Whether there is explicit cultural knowledge relating to the management of gene flow among varieties (or whether gene flow is managed tacitly, or even unintentionally, through practice) in two crops with different breeding systems.
- And whether, and how, this knowledge is shaped by social factors, specifically by gender (whether it belongs explicitly to the domains of men and women and is seen as an element in gender identity).

<u>Why Western Division and particularly Tujereng as a main research site?</u>

As main research site the village of Tujereng along the coast in Western Division was chosen. After the Sahelian droughts in the 1970s and 1980s, agricultural extension and NGOs assisted farmers to replenish their seed stocks and supplied short duration varieties of various crops. Compared to the rest of the country, Kombo (the western part of Western Division, see Figure 1.1) received relatively little attention from agricultural extension and NGOs in terms of new seed and new varieties. The village of Tujereng was visited once in 1980 by an agricultural extensionist, called Banghura, who introduced a 3-month rice variety. The National Agricultural Research Institute (NARI) conducted a PVS-trial from 1998 to 2000. Tujereng thus provides a good opportunity to study a traditional farmer seed system little influenced by extension and research activities.

With close to 2000 inhabitants, Tujereng is a big village. Originally it was a Mandinka settlement, but because of the rebel war in Casamance, in the past 20 years many Jola from Casamance have settled in Tujereng. Although it is situated only 25 km from the urban areas (Serrekunda, see Figure 1.1), it was rather isolated until the year 2000 because the connecting dirt road was extremely hard to travel during the rainy season. Just before the rainy season of 2001, a tarred road reached Tujereng connecting Tujereng to the nearby urban centres.

To do a comparative geographical study on genetic diversity in rice and millet, three other villages were selected: Kitti, Faraba and Janack. Because of the shape of the country, these villages were selected to form a line from West to East. Distances between Tujereng, Kitti and Faraba are about 20 km and between Faraba and Janack about 30 km (Figure 1.1).



●	Major town	A	Tujereng	G	Kartung	WD	Western Division
■	Research site	B	Kitti	H	Jiroff	NBD	North Bank Division
1	Banjul (Capital)	C	Faraba	I	Massembe	LRD	Lower River Division
2	Bakau	D	Janack	J	Damfakunda	CRD	Central River Division
3	Serrekunda	E	Batabut Kantore	K	Sanending	URD	Upper River Division
4	Brikama	F	Sangajor				

Figure 1.1: Research sites and main urban centres

One of the main criteria to select these villages was that male farmers should grow late millet and that the villages would have considerable areas of uplands or transitional zones for rice cultivation (for an explanation on rice ecologies, see Chapter 3). Another criterion, which also applied to Tujereng, was that rice cultivation had been practised in the same ecology for many years. Unlike in Tujereng, farmers from Faraba and Kitti suffered from droughts in the past and some farmers had lost part of their harvest. In these two villages NGOs and extension had built dikes and distributed rice seed to the farmers. In the case of Janack it was said that farmers had been growing rice continuously, but later on it appeared that, actually, during the droughts in the 1980s farmers stopped growing rice. About 10 years ago, a NGO re-introduced rice cultivation by bringing short duration varieties to the village and since then farmers themselves have searched for other suitable varieties, both in The Gambia and in Senegal.

Kitti and Faraba are big villages, where both Mandinka and Jola live. Janack is a small village consisting of several nuclei and inhabited only by Jola. Kitti is about 7 km away from the urban areas, and until 2002, connected only via a dirt road (not as bad as the one to Tujereng). Faraba is situated further away from the urban areas along the Gambian highway going to the eastern part of the country, the country's lifeline. Janack is situated 5 km away from the highway, but remains accessible during the rainy season. Compared to the other three villages, Janack is furthest away from the urban areas and consequently can be described as a typical rural community. During the interviews in Janack, a number of farmers from Kobokorr, situated along the highway, were also interviewed because they share their rice fields with the farmers from Janack.

Interviews and measurements

To become familiar with farmers' practices, semi-structured interviews were conducted on rice and millet in Tujereng in the year 2000. In these interviews, questions were asked about farming practices, variety management, seed selection and some socio-economic factors. In total, men and women from 15 compounds were interviewed. To estimate chances of gene flow in upland rice fields, rice fields in 3 areas in Tujereng were measured. As starting point for these measurements, some of the interviewed women's fields were selected, after which adjacent fields were measured. Then, the women whose fields we measured and their husbands were interviewed. Of randomly selected husbands the millet fields were measured. In total 29 rice fields and 11 millet fields were measured and 40 compounds were interviewed, men and women separately. At flowering time, rice fields were visited twice a week to record intensity of flowering and informal interviews were conducted with the farmers.

At harvesting time, seed samples were collected of rice and millet. Because rice ripens earlier than millet, millet samples were collected at a later stage. In the villages of Janack, Faraba and Kitti (in chronological order) rice farmers were interviewed in their fields, and seed samples collected. The sampling was not done most extensive in Tujereng and the number of compounds interviewed per village (apart from Tujereng) ranges from 11 to 17. At a later stage, the husbands of the interviewed rice farmers in these three villages were interviewed and millet seed samples collected. The interview questions for the year 2000 are shown in Appendix 1.

In 2002, a countrywide questionnaire was conducted in 11 villages to compare cultivation and seed management practices in other parts of the country with the 4 villages already interviewed. Depending on the size of the village, 10 or 20 compounds were interviewed. In the case of Tujereng, a random selection was made of the 40 compounds already interviewed in 2000. Because of the small size of Janack, compounds interviewed in 2000 were interviewed again in 2002. In all other villages (including Faraba and Kitti), compounds were selected at random, using taxpayer lists. In each compound (as in 2000) one man was interviewed about millet, and one woman about rice. This means that farmers in Janack and Tujereng were interviewed twice about the same topics. In the 2002 questionnaire some questions were added to the interviews of 2000. Other questions were phrased in a different way. A few questions, for example on variety management, were the same as in 2000, but needed to be asked again to be able to make a comparison with the other villages legitimate. The 2002-questionnaire for rice is shown in Appendix 2.

The interviews were conducted in the following districts (from West to East):

- Kombo: Apart from Tujereng, Kitti and Faraba, the village of Kartung, along the coast, was selected (Figure 1.1). The reason to include this village was to make a comparison with Tujereng about variety management. We were told that farmers in Kartung grow upland rice, but farmers in fact appeared to concentrate on lowland rice.
- Foni: Apart from the Janack, the villages of Batabut Kantore and Sangajor were selected. Climatic conditions are similar to those in Kombo, but whereas the rural areas of Kombo are influenced by the nearby urban areas, Foni is typically rural.
- Kiang: The villages of Jiroff and Massembe were selected. Ecological conditions are different from those in Kombo and Foni. In Kiang, men grow early millet, instead of late millet, and women grow rice in seasonally salt-water swamps, whereas in Kombo and Foni women grow rice in fresh-water swamps. In Kiang, some farmers of two other villages were interviewed where both men and women are involved in millet cultivation, although separately from each other. Because of small numbers these interviews were not included in the analysis.
- Fuladu: The villages of Damfakunda and Sanending were selected. In these villages, a different type of late millet is grown from that in Kombo and Foni. These villages are also furthest away from the urban areas in the western part of the country.

From 2001 to 2003, the farmers from Tujereng interviewed in 2000 were interviewed again about their variety management of rice and millet. From 2001 to 2003, some farmers in Tujereng were also interviewed in depth in a more informal way. In 2003, farmers of 10 compounds in Tujereng and Faraba were asked to group rice panicles and millet spikes (details are described in Chapter 9). In 2003, part of the information collected during the fieldwork was discussed in a workshop with farmers in Tujereng.

From 2000 to 2003, various kinds of information on aspects of Gambian agriculture were gathered from researchers of the National Agricultural Research Institute.

Field trials

The following field trials were conducted:

- In 2001 and 2002, trials were conducted to enable morphological comparison within and between varieties of both rice and millet. For details see Chapters 4 and 10.
- In 2002, those rice samples collected in Kombo and Foni during the 2002 questionnaire were sown in one-replication trials to observe growth habit and time of flowering (see Chapter 6).
- In 2002, four small millet trials were conducted in Tujereng, Kitti, Faraba and Janack to measure growth and adaptation of four seed samples. Further details are described in Chapter 11.

Definitions

To avoid confusion, definitions of certain terms as used in this thesis are now offered:
Activity-gendered refers to men and women doing different tasks on the same crop.
Crop-gendered refers to men and women growing different crops.
Genetic diversity is all diversity that can be found within one crop species, based on morphological and/ or molecular analysis.
Farmers varieties are varieties selected and developed by farmers, and include both varieties which have been with farmers from time immemorial (old farmer varieties), and those relatively newly developed or obtained from other farmers or villages (new farmer varieties). Traditional varieties and landraces are considered synonymous with farmers' varieties.
Formal varieties are all varieties that are developed by plant breeders (usually called modern or improved varieties); this includes those developed long ago and more recently.
Seed lots refer to the seeds of the same variety held by different farmers (see also Louette *et al.* (1997)).
Founders are those people and families belonging to the founding lineages of a village.
Strangers are people who settled in a village at a later stage. In local usage, people whose forebears entered a village as strangers continue to be classed as strangers.
Strange farmers are people who temporarily settle in a village for farming. The term is accepted usage for temporary migration in The Gambia (see Swindell, 1980).

1.7 Chapter outline

In the following chapters, results on rice are usually discussed first, followed by results on millet. Because of gender differentiation in rice and millet cultivation, in those sections discussing only rice the word 'farmer' automatically refers to women, while in those sections discussing millet the word 'farmer' automatically refers to men.

Chapter 2 gives an introduction to the main features of Gambian agriculture, and the changes over the past 150-200 years, starting from the transformation of groundnuts into a cash crop. It discusses how climatic changes, socio-economic changes and global economic developments affect local farming systems in The Gambia and how farmers adapt to these changing conditions.

Chapter 3 describes the cultivation methods of rice and millet used by the farmers interviewed. In the first place, it provides basic information for understanding Chapters 4 to 8. It also supports information in Chapter 4 on the kind of selection pressures the cultivation methods exert on varieties and seed lots.

Chapter 4 describes farmers' selection methods for rice and millet. It also discusses the possible impact of farmer selection, agronomic factors, ecological factors and social factors on changes in varieties and seed lots.

Chapter 5 describes farmer variety portfolios and variety management. This chapter discusses various aspects at the farmer level such as number of varieties used, variety criteria, variety choice in relation to farming practices and variety replacement. Further, it discusses the use of formal varieties, and the decline in the use of African rice.

Chapter 6 describes seed flows and variety naming. Since the formal sector plays a limited role in the distribution of rice and millet seed in The Gambia, most of this chapter describes the informal seed sector. In relation to seed flow aspects are described such as seed loss, seed and variety exchange, and seed and variety sources. Variety naming gives a better insight on seed and variety flows within and between villages.

Chapter 7 explains the lay-out of fields, the level of diversity in fields, and discusses the chances for cross pollination in the field, between fields, varieties, and within fields and plots. It also discusses what farmers do with off-types they find in their field, and whether gender plays a role in the cultural understanding of off-types.

Chapter 8 discusses the occurrence of wild and weedy relatives and what farmers do with the wild and weedy relatives of, respectively, rice and millet. Based on that, the chances of cross-pollination between the cultivated and wild species are discussed.

Chapter 9 discusses variety management from a gender perspective. Linking back to Chapters 2 to 8, differences between men and women in relation to crop choice, cultivation methods, variety choice, variety testing, seed loss, seed storage, seed exchange, separation and development of new varieties in the field, seed selection and description of varieties are assessed.

Chapter 10 compares the number of varieties identified using morphological data on the number of varieties identified in interviews. Furthermore it discusses the morphological and molecular diversity of rice and millet between villages and between farmer and formal varieties of rice. It also discusses changes in genetic diversity in rice and millet over time.

Chapter 11 describes local adaptation in millet. It also links back to Chapter 2 to discuss how farmers adapt to the changing agro-ecological and socio-economic conditions and whether variety management has played in role in this.

Chapter 12 summarises the information from the previous chapters and elaborates the formula on gene flow. The chapter discusses how the informal and formal seed sector can be linked to each other in more efficient ways, and what role Participatory Varietal Selection and Participatory Plant Breeding might play in improving low-input farming systems in The Gambia.

1.8 An overview of the argument of the thesis

Much farmer oriented seed research in the past 10 years was geared towards farmer seed selection with the idea that understanding farmer seed selection is instrumental in improving farmer crop development. The information in this thesis, however, will suggest that farmer seed selection practices play only a small role in farmer crop development, particularly for inbreeding crops. It needs to be mentioned here that in this thesis a distinction is made between farmer seed selection to procure seed for the next growing season and farmer off-type selection to separate uncommon, unfamiliar and new materials, originating through seed mixtures or cross-pollination, for testing. This thesis suggests that two complementary processes - seed exchange linked with variety choice and cross-pollination linked with off-type selection - contribute most to farmer crop development. This, in fact, is not much different from standard plant breeding theory, which indicates that generation of diversity and selection from that diversity are essential for progress.

The thesis compares farmer crop development in two crops with different breeding mechanisms; an inbreeding crop, rice, and an outbreeding crop, millet. From time to time, female farmers develop new rice varieties, whereas male farmers do not develop new millet varieties. Because millet is an outbreeder and morphologically very diverse, developing new millet varieties is more difficult than in rice. Furthermore, even though there is no difference in the capacity of men and women in differentiating rice and millet varieties, handling many varieties and selecting and testing new varieties is seen as typical women's activities and part of women's identity by both men and women.

It can be hypothesised that the genetic diversity within millet varieties provides adaptation to changing conditions, whereas the active exchange of rice varieties and development of new rice varieties is necessary to keep the system adaptable. As such, the millet seed system can be considered low-cost and more robust, whereas the rice seed system is more a higher maintenance and less robust system, needing constant exchange and testing of off-types to keep it adaptable. However, the information in this thesis cannot provide conclusive proof of this argument because crop phenology of rice and millet are different and ecological conditions are less diverse for millet than for rice.

In the last chapter various options are described to improve formal crop development or to link it better with farmer crop development. Not only can formal crop development be improved by developing varieties that fit farmers' needs better, but there seems to be scope to improve the selection process of conventional breeding programs.

2 Dynamics of Gambian agriculture

2.1 Introduction

One of the main questions of this thesis is whether, and if so how, seed flow and pollen flow play an important role in the adaptive capacity of Gambian agriculture. This chapter illustrates the dynamics of various economic, climatic and social factors shaping Gambian agriculture, indirectly affecting seed and pollen flow. The chapter ends with describing the changes in farmer crop portfolios, land use and crop yields. Crop portfolio is used as an indicator how Gambian agriculture adapts to changing conditions over time and crop yields as indicator on the resilience of Gambian agriculture. The role of seed selection, seed flow and pollen flow will be described in the following chapters. This chapter also provides an overview of Gambian agricultural in general.

The chapter starts with a short description on the rise of groundnut as a cash crop in the early 19th century. The reason to start with groundnut in a thesis on rice and millet is that it induced various economic and socio-cultural effects on rice and millet cultivation. One of the main effects of the commercialisation of groundnuts is that, nowadays, Gambian agriculture has a different gendered labour division than prior to groundnuts becoming a cash crop (Watts, 1993). Before the commercialisation of groundnuts, both men and women were involved in rice farming in The Gambia. In the second half of the 19th century men left all work in the rice fields to women, except the clearing of the fields, because of property aspects related to field clearing (Watts, 1993). This then means that what is sometimes called the typical Mandinka farming system (Webb, 1992) has only existed for roughly 150 years.

For almost all ethnicities of The Gambia agriculture is gendered nowadays. In the northern part of Casamance, south of the Gambian border, Olga Linares (1992) speaks of a process of 'Mandingisation' of the Jola: The Jola adopt the culture and religion of the Mandinka. In The Gambia this not only happened with the Jola, but also with other tribes (Box 2.1). In Fula villages where not long ago women gave up rice cultivation because of lack of rainfall men and women have separate millet and groundnut fields (see also Chapter 9). Only among the Manjago, men and women work together in the same fields on rice, millet and other crops. The Manjago only settled in The Gambia relatively recently (early 20th century) and originally come from Guinea-Bissau where rice farming is task-gendered (men and women responsible for different tasks).

2.2 Socio-economic changes

Economic change from 1800 to 2000

Commercialisation of groundnut cultivation

After the British abandoned the Atlantic slave trade in 1807, the Gambian economy needed a substitute for the slave trade (Quinn, 1972). Although the Portuguese had introduced groundnuts as far back as the the sixteenth century, its cultivation was negligible till the 1830s. In those days groundnuts were grown as a safeguard against the failure, or partial failure, of millet (Morris, 1985). Table 2.10 indicates that during this period rainfall was low and possibly farmers were looking for alternative crops.

Groundnut also came to be used as a subsidiary food and sauce and its leaves as fodder for horses (Brooks, 1975). Records indicate the early 1830s as the start of substantial groundnut exports from The Gambia (Brooks, 1975). The growing demand for oils and fats in industrialising countries in Europe triggered the export of palm oil and groundnuts from West Africa (Brooks, 1975). In 1840, the French removed the protective duty on olive oil, which made the price of groundnut cheaper in France, and in the late 19th century the popularity of margarine led Germany and The Netherlands to enter the trade (Swindell, 1992). Several other factors further stimulated the export of groundnut. One factor was the American Civil War which strangled the supply of cotton-seed oil to Europe (Webb, 1994). Because The Gambia is situated on the Atlantic Ocean and the river Gambia is easily navigable far inland, transportation costs were relatively low, which also worked to the advantage of the producers (Webb, 1992).

Box 2.1 Ethnicities of The Gambia

Most Gambians consider the Mandinka to be the first settlers of The Gambia. During the expansion of the Mali Empire in the fourteenth century, the Mandinka, following the Gambia river, pushed the Jola south and the Serer to the north into Senegal (Quinn, 1972). The Jola, presumably related to the Serer, probably represent some of the earliest inhabitants of the Gambia valley.

Even though The Gambia is one of the smallest countries on the African continent, it is inhabited by peoples with a range of ethnicities, of which the Mandinka form the largest group (42%), followed by the Fula (18%), Wolof (16%), Jola (10%) and Serahuli (9%). Serer, Aku and Manjago are some of the better known minorities. Because the Mandinka represent 42% of the population, many people of the other ethnicities also speak Mandinka. Before the second half of the 19th century not many Wolof lived in the Mandinka states along the Gambia river. But nowadays, the Wolof are the third largest population group in The Gambia and Wolof is the lingua franca in the urban areas and the second common language in the rural areas, after Mandinka.

Possibly because Islam suits nomads (Trimingham, 1961) and because Fula are pastoralists, they were the first to convert to Islam and during the 19th century other ethnicities followed. The Jola were the last to convert to Islam in The Gambia. Aku and Manjago form a Christian minority. In southern Casamance (in Senegal) most Jola have not converted to Islam (Linares, 1992).

Each ethnicity has its own language and, superficially, next to religion, language seems to be the main difference between ethnicities. Ethnicity however is also a somewhat flexible concept: When children of Wolof immigrants grow up in a Mandinka village they sometimes call themselves Mandinka, while their parents are Wolof. Because in most areas Mandinka is the dominant tribe, most people who change ethnicity become Mandinka. In this respect, there is an interesting anecdote about Kombo area (see Figure 1.1) as a whole. With the expansion of the Mali empire, the Mandinka pushed the Jola southwards out of Kombo area. Many of these Jola, however, resisted and were named 'Bojang' which means in Mandinka 'go away from here'. Nowadays, all Bojangs born in Kombo consider themselves typical Mandinka, and many Mandinka villages in Kombo, like Tujereng and Kitti, are founded by Bojangs. The Bojangs in Foni, however, are Jola and still consider the Bojangs in Kombo to be Jola in origin.

Olga Linares (1992) speaks of a process of 'Mandingisation' of the Jola in the northern part of Casamance: The Jola adopting the culture and religion of the Mandinka. In Kombo it is likely that this process went a step further and that many Jola became Mandinka. In Foni Jola adopted the culture and religion of the Mandinka, but also retained some of their own cultural traditions. This not only happened with the Jola in Foni, but also with other tribes in other parts of The Gambia. Curtin (1975) argues that living as neighbours over several centuries also led to interchange between the Mandinka and the Serer and Wolof living in The Gambia. Hart (1982) mentions a process of Wolofisation in northern Senegal, where the Wolof are the dominant ethnicity. Nowadays, particularly in the urban areas where so many different ethnicities live together in the same small space, adoption of cultures continues to take place and differences between cultures will tend to decrease further.

Farmers responded to the new crop with remarkable swiftness and groundnut commercialisation had far-reaching economic and social changes for the people of The Gambia (Brooks, 1975). At first, groundnuts were only cultivated by Gambian farmers, but soon 'strange farmers' from the north and east of The Gambia became involved, usually as seasonal labourers (Quinn, 1972). Another social change was the changed labour division in rice (to be discussed further in Chapter 9). According to Hogendorn (1976, in Barrett, 1988), the tremendous increase in exports was possible because of an existing surplus of production factors, like an abundance of open land. The other essential production factor, labour, became available through the collapse of the slave market, which made it impossible for local traders to export their slaves.

In some cases these slaves were made free, while in other cases they were set to work by their masters (Hart, 1982). The coastal elites used these slaves, through the cultivation of groundnuts, to restore their income, and maintain their prestige and power in the emergent European dominated system (Hart, 1982). For farmers of the lower classes groundnut cultivation was also very lucrative. They had to give only the leaves of the groundnut plants as a tax to the local rulers, which farmers did not need anyway (Wright, 1997). With the sale of the nuts farmers could gain access to commodities that previously only the ruling elites could afford. This also explains why so many people from outside The Gambia engaged in growing groundnuts. These migrant farmers, in turn, also supplied the necessary labour for local farmers to expand their groundnut cultivation (Swindell, 1992).

Despite the huge external demand for groundnuts, the English trading community felt Gambian farmers should increase their production. Consequently, the colonial government stimulated production by introducing taxes that could only be paid in cash (Barrett, 1988).

<u>The effect of groundnut cultivation on food production</u>

Because of the high profits of groundnuts, male farmers concentrated more on groundnut production and less on food crops (Watts, 1993; Swindell, 1992). Whereas before 1800, The Gambia was known as a food exporting country (Carney, 1989), it quickly became a food importing country after the boom in groundnut trade (Figure 2.1). After World War II, the British government began to modify its policies, and particularly the years 1948-1951 saw a major but unsuccessful attempt to diversify Gambian exports (Barrett, 1988). With the introduction of animal traction in the 1950s men increased the size of their groundnut fields even further, at the expense of food crop production (Weil, 1970).

In the 1950s, the colonial state funded mangrove clearance, the construction of causeways and footbridges to improve access to the deep-water swamps and the distribution of formal rice varieties, so that in the central part of the country women were able to increase their rice production, which balanced the decrease in (millet) food production by men (Watts, 1993; Haswell, 1991) and even enabled the men to increase groundnut production even further (Weil, 1973, Haswell, 1975). In these areas women were able to increase their rice production, not only because they had access to more fertile fields (compared to the less fertile upland fields), but also because they started working in the rice fields at an earlier age and left the work at a later age (Webb, 1992; Haswell, 1991). Because of their increased production, women could sell surplus rice and were able to increase their financial independence (Weil, 1973). The surplus in rice was sold on the Banjul market reducing profit margins for rice-importing merchants. In 1954, under pressure from the merchants, the state prohibited the export of rice from the protectorate and stopped completely its flow from the provinces (Watts, 1993). However, in the 1950s awareness also arose that the uncontrolled importation of cheap rice would run counter to the development of a strong domestic rice industry (Haswell, 1963). By the mid-1960s, rice production increases in the mangrove swamp ecology halted because of labour shortages. Further gains in food availability would only be possible by altering the gender division of labour, drawing men into rice growing (Carney, 1993). Whether machinery can reduce labour in such swampy fields is unclear. Gambian women, however, are very reluctant to use machinery in rice cultivation (Baker, 1995). One fear seems to be that through machinery men will gain more control over rice production.

Government policies to increase food production after independence

With independence in 1965, the Gambian economy changed little and groundnuts remained the main export product, although plans were discussed to diversify the economy and increase the domestic production of food (Wright, 1997). However, the first development plans of the government concentrated predominantly on the development of the urban areas at the expense of agriculture. Only in the early 1980s did rural development become the government's first priority with strategies developed to include investments in rural road and river communications, subsidised agricultural inputs and produce and improvement of the agricultural extension services (Barrett, 1988). This plan also aimed to reduce inequalities and wanted to achieve this by concentrating on three objectives:

a) to improve nutritional standards in rural areas,
b) to eliminate bulk cereal imports, in particular rice, by 1990,
c) to diversify rural cash crop incomes.

The aim to eliminate cereal imports, predominantly rice, skyrocketing since the early 1970s (Figure 2.1), represented an attempt of the government to reduce its trade deficit. To reduce the dependency on rice imports more than 4000 ha of rice swamp fields were converted into irrigated rice fields suitable for double cropping (Carney, 1992). Up to this day, the Gambian government emphasises food self sufficiency through increased rice production (Marong *et al.*, 2001), but has yet to be successful. Population growth has not slowed and yet Figure 2.7 shows that the total area cultivated with rice has declined since the early 1970s. In particular, reduction in rainfall in the 1970s led to a decrease in areas suitable for rice cultivation. Additionally, about half of the irrigated rice fields are unavailable for irrigation due to lack of resources (Marong *et al.*, 2001). Although rice yields have increased (Figure 2.9), these are not sufficient to balance the decrease in cultivated area and rising demand for rice. The government also tried to increase millet and sorghum production but again failed. One reason is that male farmers find it unattractive to produce more food after having been engaged in a monetary economy for 150 years (Barrett, 1988).

In the early 1980s, government efforts to increase agricultural production through input subsidies, free services and cheap credit resulted in a clear yield increase of all crops (Figure 2.9), despite the poor rainfall in those years. Farmers recall those years as vibrant and hopeful. Eventually, a combination of inefficient program management, unsustainable investments, unfavourable growing conditions and deteriorating world groundnut prices (Figure 2.2) led to a crisis of government expenditure in 1985 (Puetz, 1992).

Government policies after ERP in 1985

To be able to attract more donor funding, the Gambian government had to restructure its budget, which resulted in the implementation of the ERP (Economic Restructuring Program) in 1985 and consequently agricultural subsidies were decreased and many extension officers retrenched (McPherson and Posner, 1991). In the early 1990s, the ERP in The Gambia was generally seen as of one of the few examples of a successful structural adjustment plan (Dorosh & Lundberg, 1993). According to Radelet (1992), the decline in world rice prices (Figure 2.3) was an important factor in the achievement of this success. Low world rice prices also meant relatively low prices for imported rice in The Gambia. Even so, the local price for imported rice doubled between 1980-1981 and 1984-1985, and more than doubled again in the four years following the implementation of the ERP in 1985 (Schroeder, 1997a). The increase was primarily the result of the devaluation of the Gambian currency, the Dalasi.

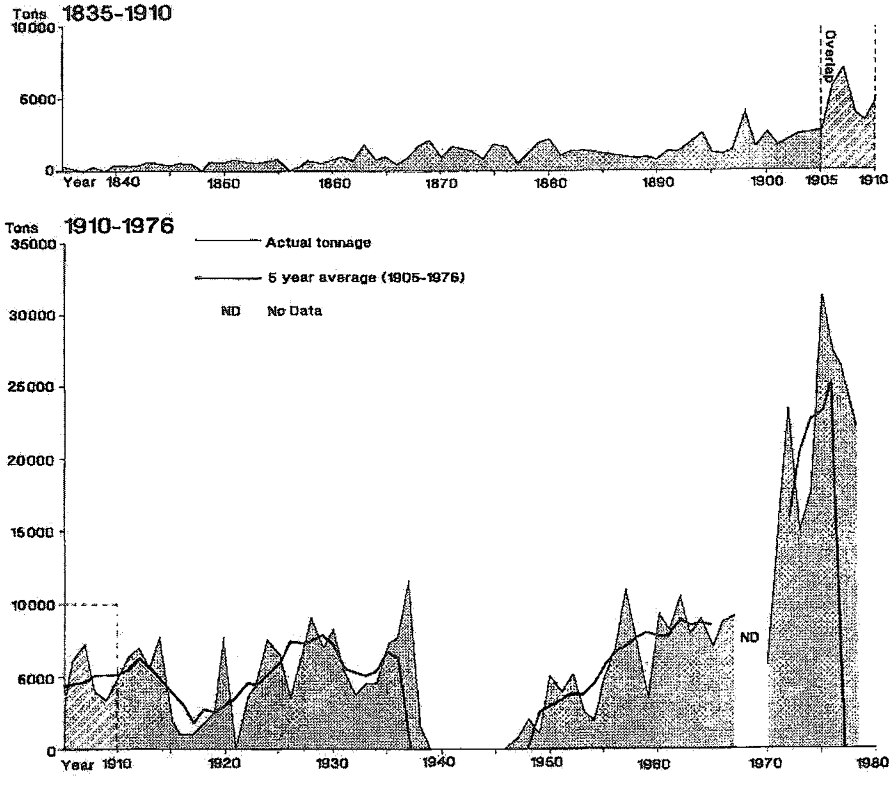


Figure 2.1: Rice imports from 1935 to 1975 (from Barrett, 1988).

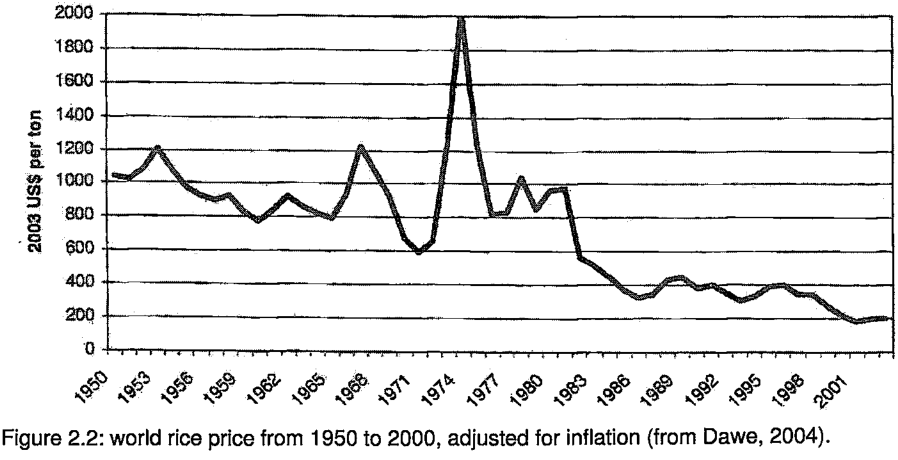


Figure 2.2: world rice price from 1950 to 2000, adjusted for inflation (from Dawe, 2004).

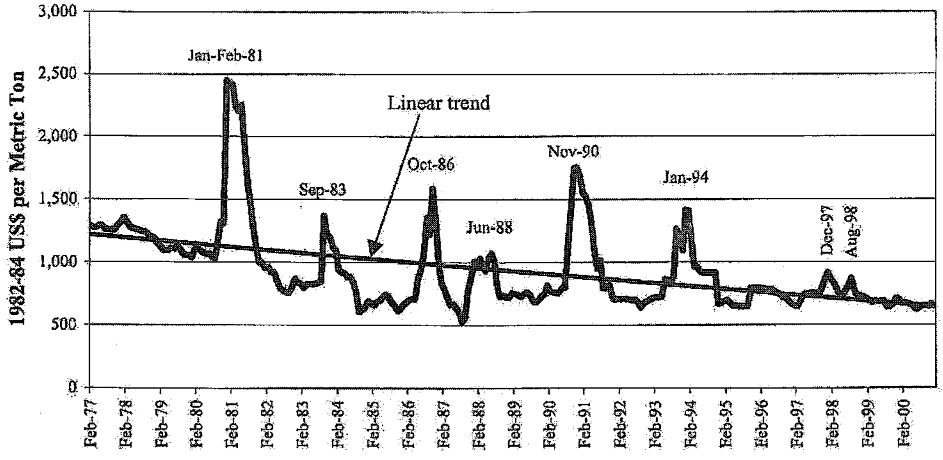


Figure 2.3: World groundnut price based on the 40/50 standard edible grade in Rotterdam (from Revoredo and Fletcher, 2002)

With the high world groundnut prices in the 1960s and early 1970s the government was able to smooth out fluctuating producer prices. Around 1980, world market price for groundnuts decreased (Wright, 1997). After 1985, the government was not able to control producer groundnut price fluctuations anymore. High prices in 1986 caught farmers by surprise, while in 1987 groundnut prices were very disappointing because they were lower than expected (Puetz, 1992). As a result, many farmers lost confidence in farming, but did not know any good alternative. In the late 1970s and early 1980s, cassava seemed to be a good alternative to groundnuts, but was whipped out in one year by the mealy bug (Jobe, personal communication). From 1980 till 1985, fertilisers were subsidised and widely used, but after the ERP they became more expensive and, according to farmers, less available. Since the ERP, most buildings of the extension service stand empty. In the village of Tujereng nobody has seen any extension officer since then, whereas before, extension officers would come regularly to train farmers. And although low world rice prices means low prices in the shops, it also means that rice farming in most ecologies in The Gambia is not economically viable (Kargbo, 1983) and consequently that there is hardly an incentive for farmers to increase their production.

The openness of The Gambia's economy has made it especially sensitive to world price shocks and its dependence on agriculture keeps it vulnerable to changes in climatic conditions (Dorosh & Lundberg 1993). To make the Gambian economy less dependent on the world economy the Gambian government continuously stresses the importance of becoming self-sufficient in rice (Marong *et al.*, 2001). However, nowadays about 80 to 90% of all rice consumed in The Gambia is imported and the total cultivated rice area continues to decline (Figure 2.7). This means that in most rural areas farmers are not self-sustaining in rice and it will be very difficult to change The Gambia from a rice importing country into a rice self-sustaining country.

Furthermore, education started to bear fruit in the rural areas in the late 1980s, with the result that young males would rather go to the urban areas to look for a 'modern' job instead of being stuck in a village, destined to farming, and consequently a low and insecure income (Wright, 1997). Not many youth want to engage in masonry, carpentry or car repairs either. These crafts can give better income than an office job, but the youth learned in school that such jobs are backward.

International policies to improve food production in The Gambia

After the decline in rainfall in the early 1970s, international development efforts emphasised improved production of rice and vegetables, both traditionally grown by women (Carney, 1992). A common view held by UN, World Bank and NGO officials was that if women earn more money, their children benefit from it (Baker, 1995). Rice and vegetables have emerged as central to donor and state efforts towards economic restructuring, but the commercialisation of rice (applicable only to the irrigated fields in the eastern part of the country) and vegetables has proceeded amid a welter of conflicting productivity and equity objectives (Carney, 1992; 1993; Schroeder, 1997a; 1997b). For example, there was no precedent for household heads to invoke female labour obligations for two cropping seasons a year (Carney 1992).[3]

Reorientation in trade

Before the colonial era, trade was very much orientated towards the east, to the Mali Empire, and to the north, towards Northern Africa (Curtin, 1975; Barry, 1981). In West Africa the river Gambia served as a commercial axis of east-west trade and north-south trade (Barry, 1981). With the arrival of Europeans from the 15th century onwards, seaward trade became more important, first in slaves, and later in groundnuts. Colonial rule reduced the movement of traders, particularly long-distance traders (Colvin, 1981). The cultivation of rice and millet decreased as a consequence of the booming trade in groundnuts in the first part of the 19th century, resulting in a decrease in trade of rice and millet. The westward trade of locally produced rice was gradually replaced by an eastward flow of imported rice. Because no millet is imported from overseas, the trade in millet has not changed in direction, though it has probably declined.

Population increase and social change

After World War II, the Gambian population increased from an estimated 294,000 in 1950 to 1,500,000 people in 2003. Table 2.1 shows that the proportion of people living in the rural areas has decreased and that, in particular, young men go to the urban areas to look for a better future. From the 1970s onwards, the male/female ratio in the agricultural labour force gradually reduced from 105/100 in c. 1950 to 96/100 in c. 2000, which is projected to continue (Table 2.1). Haswell mentioned this development, which was facilitated by the construction of a West-East road on the South bank of the river Gambia, as early as 1963. Before 1950, there were

Table 2.1: Gambian population from 1950 to 2010, rural population, as total and as percentage of the total population, total agricultural labour force, the ratio of male / female agricultural labour force, cultivated area per capita and total cultivated area (combined data from FAOSTAT and Worldbank databases).

year	total population (x 1000)	rural population (x 1000)	as % of total population	tot agric labour force (x 1000)	ratio male / female agric labour force	cultivated area (ha) / capita	total cultivated area in ha (x 1000)
1950	294	266	90.5	149	1.05		
1960	352	314	89.2	173	1.06	0.90	156
1970	464	403	86.9	213	1.05	0.75	160
1980	641	541	84.4	278	1.03	0.51	141
1990	928	760	81.9	386	1.00	0.44	170
2000	1303	1,029	79.0	528	0.96	0.43	228
2010	1626	1,231	75.7	638	0.93		

[3] Because there is already extensive literature on the effects of international development efforts on irrigated swamp rice production, and the present thesis does not deali with this ecology, the interested reader is referred to Carney (1992; 1993).

Box 2.2 Communication and agriculture

Since in 1997 the Gambian Radio and Television Service started broadcasting, covering 60% of The Gambia, people could see with their own eyes what the western world looks like. Nowadays, it is also possible to receive channels like CNN and many others through satellite-TV in the urban areas. Particularly for the youth, this gives the opportunity to compare with their own eyes the world they live in and they world they want to live in. Furthermore, soaps and the like show a different view on social relationships. For particular soaps, sometimes up to 100 youth are sitting in front of one small TV in the village of Tujereng. With recent advances in mobile telephone and internet, it is much easier for Gambians to get first hand information from Gambians abroad.

hardly any schools outside the urban areas, which changed slowly after 1950. Nowadays, children have access to primary schools in every village, but secondary education is still scarce and more common in the urban areas. With improved access to education and declining income from farming, migration to the urban areas is further accelerated and it would be interesting to study the impact of improved communication (internet, and alike) on this development (Box 2.2).

Income sources

In the past, farming was the main income generating activity, and the sale of groundnuts provided a relatively reliable income. Haswell (1975) found that while some young men who migrated from the village of Genieri to the urban areas were better off, others would have been better off if they had stayed in the village. With the declining groundnut prices in the late 1970s and the unpredictable price fluctuations in the 1980s, younger farmers lost faith in farming. Cash crops like cassava, watermelon, mango and oranges can give a very reasonable income, particularly when compared to the traditional cash crop of The Gambia, groundnuts, but also when compared to an average office job. However, it is not clear whether these crops will provide a good income in the future. Apart from all the other reasons mentioned earlier, this uncertainty is another important reason why the younger generation turns away from agriculture.

Since the late 1940s, Gambian farming has moved from subsistence farming towards a more commercial kind of farming (Haswell, 1991). It is quite common that with the commoditisation of rural production systems in Africa that women's contribution to subsistence production increases (Whitehead, 1984). This also happened with the commercialisation of groundnuts in The Gambia, However, when in the 1950s men emphasised more on cash-crop production to adapt to an increasingly commercialised economy, by intensifying rice farming, women adapted to the commercialising economy and gained economic independence from men (Weil, 1973; Haswell, 1975; Webb, 1992). Possibly, women's sphere of influence fluctuates over time: decreasing with the commercialisation of groundnut in the 19th century, but increasing with increased rice farming and the promotion of vegetable gardening in the 1970s.

Many studies of West African household economies suggest that male and female spheres of activity remain relatively independent, which should be understood in terms of indigenous social organisation (Guyer, 1980). Women's interests in an independent income are supported by certain traditional rights and their interests are more clearly served by the segregation of rural occupations than by the development of a joint household type of economy which could undermine their direct access to an income altogether (Guyer, 1980). Information from the 2002 questionnaire (Appendix 2) shows that 49% of the male, and only 32% of the female farmers, in the study villages have off-farm income sources (Table 2.2) and that men have more income sources than women (Table 2.3). Table 2.3 does not give an indication about the relative importance of these income sources, but it shows that arable crops and fruit trees are the most common income sources for men and that vegetable gardening is the most common income source for women. To a large extent, vegetable gardening explains the lower percentage of women with other income sources, because it requires daily care.

Table 2.2: Percentages of men and women who have off-farm income sources for the case study districts from west to east (data from 2002-questionnaire).

	Kombo	Foni	Kiang	Fuladu	total
men (N)	49	21	14	14	98
no off-farm income (%)	47	52	57	57	51
have off-farm income (%)	53	48	43	43	49
women (N)	55	26	18	20	119
no off-farm income (%)	69	58	50	95	68
have off-farm income (%)	31	42	50	5	32

Although one would expect differences in percentages of off-farm income sources between villages near the urban areas and those further away, these differences are very small for men (Table 2.2). For women, the differences are larger and show some irregularity: In Kiang 50% of the women have other income sources, while the equivalent figure in Fuladu is only 5% (Figure 1.1). In Kiang a majority of women are not involved in vegetable gardening, which explains the high percentage of women with off-farm income sources. A possible explanation for the low percentage for Fuladu is that many women in that district have income from the sale of groundnuts and sesame.

Table 2.3: Percentages of men and women who have income from agriculture and other income sources; N = 98 for men and N = 119 for women (data from 2002-questionnaire).

	arable crops	gardening	fruit trees	other income sources	average # income sources
men	91	-	69	49	2.1
women	21	72	21	32	1.5

The promotion of vegetable gardening by aid agencies as a substitute for rice farming after the decrease in rainfall in the 1970s provided an independent income source for women (Baker, 1995; Schroeder, 1997b). In certain areas, where men's income depends largely on the sale of groundnuts and which are not sufficient anymore to sustain the family, women's income from gardening has become indispensable during the dry season (Schroeder, 1997b). Traditionally, however, it is the man's responsibility to take care of all family expenses, like food, clothing, taxes, school fees, etc. Women are supposed to be only responsible for their own expenses.

From the questionnaire conducted in 2002 it became clear that off-farm income sources are more diverse for men than for women. Men who have off-farm income sources state a variety of jobs of which the most common include: shop owner, carpenter, *marabout*, labourer, businessmen, tailor, mason, and driver. For women, the most common off-farm income source is to sell at the local market. Particularly Fula women hardly mention any other income source. Other off-farm income sources for women, often specific to one particular village, and mostly mentioned by Jola and Mandinka, include: pottery, salt production, daily labour, business, lime production, palm oil production, and cotton thread making. This suggests that women are less mobile than men in relation to income earning. Although many women do travel to nearby towns to sell their produce it is usually men who travel longer distances and probably have larger trade networks. The reason women cannot travel large distances on a regular basis is that they are responsible for various daily jobs like vegetable gardening, child rearing, cooking, cleaning and fetching water. Even when children do such work, women need to supervise.

Food preferences

Food preferences of the various ethnicities are related to the ecology. In the past, Mandinka and Jola settled in areas suitable for rice cultivation, whereas Fula and Wolof settled in areas only suitable for millet cultivation. Hence, the Mandinka and Jola are known for their rice cultivation skills. In the eastern part of The Gambia (including Kiang) it is still common to find Mandinka settlements near the river Gambia and Fula settlements in drier areas further away from the river. Nowadays, however, differences in food preferences between ethnicities are decreasing. For most people, rice is the preferred food and millet is number 2. People say rice tastes nicer than millet, and, possibly more importantly, it is much easier and quicker to prepare. The pounding of millet is an especially tough job (Haswell, 1991). In many areas - both urban and rural - many people buy milled rice in shops (which does not need to be pounded). Because 80-90% of all consumed rice is imported (Marong *et al.*, 2001) local rice prices follow world rice prices. Hence, prices of rice are much more stable than of millet, which is not imported on any large scale. Of millet, every year prices increase two- or threefold towards the beginning of the cropping season and decrease after the harvest. Apart from rice gaining in importance, in the urban areas bread has become a notable convenience food.

Comparing the relatively low prices of rice in the shops with all the hard work women do in their rice fields, it is actually surprising that farmers still continue growing rice. Apart from the fact that they do not have an alternative, another reason is that commercially available rice is of lower quality. Fresh rice is preferred for cooking during ceremonies in the village, and is more suitable for dishes like *satoo* (porridge made of rice; if raw groundnuts are added it is called *chekere satoo*). Rice sold in the shops is often several years old and therefore less suitable for *satoo*. If you do not have your own rice, you cannot contribute fresh rice to ceremonies.

In the study area all respondents said they buy rice, while only about 70% said they buy millet (Table 2.4). Since 80-90% of all rice consumed in The Gambia is imported, it is quite logical that all respondents said they buy rice. Because millet is not often sold by farmers, the 70% of the men who do buy millet probably buy millet on a less regular basis then rice. Possibly, the fact that many farmers in Kombo grow relatively small fields with millet (see Chapter 3) explains why more farmers in Kombo buy millet.

Table 2.4: Percentages of men who buy millet and rice (data from 2002-questionnaire).

	Kombo	Foni	Kiang	Fuladu	total
respondents (N)	61	29	20	20	130
buy millet (%)	80	59	65	68	71
buy rice (%)	100	100	100	100	100

Migration

With the booming of groundnut as a cash crop in the early 19th century, a large seasonal labour migration from Guinea and Mali to The Gambia emerged. This migration continued up to the late 1970s (Webb, 1992), after which it gradually declined, due to the decline in world groundnut prices and price fluctuations in the 1980s. Another seasonal labour migration that emerged in the early 20th century involves Jola from Western Casamance coming to the western part of The Gambia to cut palm kernels for palm oil (Hamer, 1981). This is because the Mandinka lost the skills to climb palm trees after they became Muslim. Palm tree climbing is associated with the tapping of palm sap as an alcoholic beverage. In addition to the rural-urban migration (from East to West) that increased from the 1950s onwards, there is a minor, seasonal westward rural-rural stream for farm labour.

Apart from the permanent rural-urban migration, there is another kind of permanent migration. Over the past 30 years, people fleeing from the fighting in neighbouring countries (mostly Jola from Casamance, but also people from Guinea Bissau and Sierra Leone) have tried to build up a life in both rural and urban areas in The Gambia. This adds a new dimension to earlier movements back and forth in response to opportunity, or pressures of war, pestilence and drought (Curtin, 1975).

Among villagers interviewed in Kombo, there were many who were designated strangers: i.e. people who moved to a village for permanent settlement (Table 2.5). Tujereng has also attracted strangers, especially because of the war in Casamance. This is a common picture for a large part of Kombo, also for Kitti. Faraba was founded by part of the population of Faraba Banta fairly recently (about 50 years ago) and this place has also attracted a large population of strangers from rural areas in the eastern part of The Gambia. In the villages in Fuladu, furthest away from the urban areas, all the men interviewed by contrast were living in the place they were born. Likewise, in Foni and Kiang there is little population mobility.

Next to the migration by whole families, there is also a traditional migration of women, when they move to a different village on marriage. This partly explains why on average 55% of the women interviewed live in a different place from where they were born, compared to only 32% of the men (Table 2.5). It is not possible to indicate, however, exactly how many women marry outside their village. The data for Fuladu suggest that up to a third of the women marry outside their village. This agrees to a large extent with the 39% of the women who are strangers, but whose husbands are not.

Table 2.5: Percentages of men and women who live in a different place from where they were born (strangers = not born in the village), per district; N = 88 for both men and women (data from 2002-questionnaire).

		Kombo	Foni	Kiang	Fuladu	total
men	born in the village	45.7	85.7	66.7	100.0	68.2
	are strangers	54.3	14.3	33.3	0.0	31.8
women	born in the village	40.0	42.9	38.1	66.7	45.5
	are strangers	60.0	57.1	61.9	33.3	54.5

Organisation of labour

In the past, migrant labour was very important because of structural labour shortages. Migrants would find a landlord for whom they worked a number of days per week and in return they got a piece of land to grow groundnuts. A question not addressed in the fieldwork is whether with population increase, labour shortage is still a structural problem. It became clear, however, that most farmers think labour shortages are still a problem.

Apart from seasonal labour migration, labour is organised for the Mandinka at the following three levels: gender, family (compound) and *kafo*. A *kafo* is a working group of men or women with a similar age (for more detailed explanation see below). For the Wolof, Jola and Fula, labour is organised in a similar way (see Dey, 1982). As mentioned earlier, rice is a women's crop and all other cereals and groundnuts are men's crops. In those areas where rice cultivation is limited or not possible women are also involved in the cultivation of upland crops. Women involved in upland rice farming depend on men to clear and burn the forest for them and to help transport the harvest from field to compound. The threshing of the cereals grown by men is left to the women, while the threshing of the groundnuts is done by the men.

Compound composition

Residential compounds can vary widely in composition. It is possible that a compound consists of only one man (the compound head), one woman and several children. It is also possible that a compound consists of the compound head, married with 2 or 3 women, who all have several children, his brother who also has a wife and children, another brother not yet married, their mother, some half-brothers and half-sisters from the second wife of their deceased father, and some cousins. Far more complex compound compositions are possible, so that some compounds consist of 100 people or more. Under the influence of modernisation, there is a trend for men to move out of their father's compound sooner to build their own compound. Because of this trend, the average number of people per compound is slowly decreasing, as reflected in Table 2.6. In Kombo, where the urban areas are situated, and Foni, closest to the urban areas, the number of people per compound is smaller than in Fuladu, which is furthest away from the urban areas. Because of this and because of variation within ethnicities, differences between ethnicities do not easily become clear. In general, Jola and Fula compounds consist of fewer people than Mandinka compounds. The changes in the number of people per compound also affect the organisation of labour in *dabadaa* and *sinkiroo* (see below).

Table 2.6: Average number of people (sub-divided into adults and children), number of *dabadaa* (male working units) and number of *sinkiroo* (cooking unit) per compound for the various districts and ethnicities in the study area (data from 2002-questionnaire).

district	# respondents	# people	# adults	# children	# *dabadaa*	# *sinkiroo*
Kombo	59	18.6	9.2	9.5	1.3	1.5
Foni	29	17.9	9.1	8.8	1.6	2.2
Kiang	20	22.0	10.4	12.0	1.9	2.3
Fuladu	20	29.3	11.4	17.9	1.4	1.5
total	128	20.6	9.7	11.1	1.5	1.8

Dabadaa and *Sinkiroo*

Labour in compounds is organised in male and female working groups for the Mandinka, Jola, Fula and Wolof. The *dabadaa* refers to the male working unit (consisting of adults and children) and the *sinkiroo* refers to the cooking unit, of which the women (both adults and children) usually also join hands in the field to form a female working group. The bigger the compound, the more *sinkiroo* and *dabadaa* there are, but in most cases there is one *sinkiroo* and one *dabadaa* per compound (Tables 7 and 8). Usually, the number of *sinkiroo* and *dabadaa* are the same in a compound, but this is not always the case. For example, it is possible for father and sons to join in one *dabadaa*, while their wives might prefer to have separate *sinkiroo*. Whether there are more than one *dabadaa* in a compound depends on the relationships and preferences of the people in a compound. Granting permission to a son or several sons to form a *dabadaa* has the advantage to a compound head that the sons will not leave the compound and that during peak labour times labour will be shared, although in general co-operation tends to decrease. Since World War II, the trend has been for patrilineal family units within compounds to fracture into relatively independent structures for production and basic economic management purposes (Weil, 1968; 1973). The inducing factor for this trend is greater economic pressures in a commercialised economic system wherein guaranteed subsistence is disappearing (Weil, 1968). The key effect is that *dabadalu* become smaller, requiring more efficient use of the remaining labour.

The number of people per *dabadaa* or *sinkiroo* varies a lot (Tables 2.7 and 2.8). The average number of people per *dabadaa* and *sinkiroo* compared to the number of *dabadaa* and *sinkiroo* per compound is quite stable (Tables 2.7 and 2.8). The *sinkiroo* (average 2.9) are smaller than the *dabadaa* (average 5.1), which, to some extent, is related to the higher number of *sinkiroo* per compound compared to the number of *dabadaa* per compound. The most important reason for the higher number of *sinkiroo* per compound is that it happens that co-wives with the same husband form separate *sinkiroo*, while their husband forms one *dabadaa*. It is also common, however, for co-wives to join hands in one *sinkiroo* to make work easier. Whether women will join hands in one *sinkiroo* depends on their relationships with each other. Working groups for men are also bigger because women have other activities like cooking, laundry and child rearing. Furthermore, pregnancy complicates working in the field (for example, bending over the whole day while weeding).

Table 2.7: Number of male per *dabadaa*, compared to the number of *dabadaa* per compound (data from 2002-questionnaire).

# *dabadaa* / compound	average # male per *dabadaa*	# compounds	std. deviation	minimum # male per *dabadaa*	maximum # male per *dabadaa*
1	5.1	91	3.28	1	15
2	5.0	21	2.01	1	10
3	4.7	3	2.52	2	7
4	3.8	3	2.08	2	6
5	7.3	3	7.09	1	15
6	5.0	2	1.41	4	6
total	5.1	123	3.13	1	15

Table 2.8: Number of female per *sinkiroo*, compared to the number of *sinkiroo* per compound (data from 2002-questionnaire).

# *sinkiroo* / compound	average # women per *sinkiroo*	# compounds	std. deviation	minimum # female per *sinkiroo*	maximum # female per *sinkiroo*
1	3.0	78	1.75	1	8
2	3.1	22	1.43	1	6
3	2.0	8	1.41	1	5
4	3.3	6	2.88	1	9
5	2.0	5	1.00	1	3
6	2.7	3	2.08	1	5
total	2.9	122	1.93	1	9

Cooking, especially, can usurp much time. In those compounds with several women tasks can be divided among the women: one woman does the cooking at home, while others go to the farm. When the woman at home has finished cooking, she also goes to the farm. In case a woman is the only adult woman in the compound and needs to do both cooking and work in the field, she will cook lunch early in the morning, take some with her, leave the rest of the food for the men and then go to the field. When she goes to the field she will take the small children with her. If there is another woman, or older child in the compound, the children can stay at home. Schroeder (1997b) describes in detail the hectic time schedules of some women who are the only adult woman in the compound. Most of the time, this kind of schedule is somehow manageable, but as harvesting approaches, when bird scaring has to be done from 7 in the morning till 7 in the evening, the woman needs other people to help her with the bird scaring. This is one of the main reasons why women in the *tandako* (uplands) have their fields adjacent to each other, to be able to keep an eye on each other's fields when necessary (see Chapter 3).

During school holidays, the children go to the field to help with sowing and weeding (boys in millet and girls in rice). But, particularly in Kombo, children are getting more and more reluctant to work in the fields. Children help less often with harvesting than with sowing and weeding, because at harvest time they need to go to school. Up-country (in the eastern part of the country) the grown-up boys are prone to leave their village to go to the urban areas to find some 'nice job' in an office (which often they cannot find). Others try to find a job in the tourist industry or talk money out of tourists' pockets.

Kafolu

A *kafo* is a working group organised by age and gender. For each gender, 2 or 3 age sets exist. In the case of women, there is a young-girls *kafo* and a married-women *kafo*. In the case of men, there is a boys *kafo*, a young-adult *kafo*, and an adult *kafo*. The organisation of *kafolu* (plural of *kafo*) can differ slightly between areas. Dey (1982), for example, describes a slightly different organisation for villages in Central River Division. In big villages there are often several *kafolu* of the same age set. Who belongs to which *kafo* depends on ethnicity, family ties and friendships. In a village with both Mandinka and Jola residents there are separate Mandinka and Jola *kafolu*.

Most farmers are member of a *kafo*, and usually they call in their own *kafo* for help with ploughing, weeding and harvesting. Another advantage of working in a group is that the work goes quicker and easier than when working alone. In a study on rice in Sierra Leone it was found that music in combination with big groups had a positive effect on the quality of the work (Johnny *et al.*, 1981). In the past, Gambian farmers did work with drums, but not anymore. Being member of a *kafo* also means that it is possible to earn some extra money by working for those who are not member of the *kafo*. If *kafo* members call their own *kafo*, they only need to provide food during that particular day.

A *kafo* will charge an amount of money per day according to the size of the group, not according to the amount of work that needs to be done[4]. This is also the reason why some *kafolu* will not admit more people if their group has reached a certain number of people. It would mean that it would be more difficult to find work. When a *kafo* consists of a large number of people it will also be difficult to decide which members' field first to plough, weed and harvest, and equally important, whose field last. Such decisions are very important because the time window for sowing is very short, because of a short rainy season.

Since the female *sinkiroo* working groups are smaller than the male *dabadaa* groups, it is more common for women to call in the help of their *kafo*, indirectly reinforcing the bounds between *kafo* members more than is the case in male *kafolu*. Another possibility for women is to call in help from reciprocal labour groups, consisting of maximum 10 women, made up, often, of friends or relatives (Dey, 1982).

Land ownership

In the traditional system of land ownership, most, if not all, land is owned by men of the founding lineages of the village and later on, depending on the availability of land, either lent or given to other men who settle in the village later (so-called strangers). If a lineage moves or dies out, the land it owned can be reallocated by the village head to those who are short of land,

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[4] The *kafo* working in my rice trials charged more money in 2002 than in 2001, because the group increased to 30 people (although usually only 18-22 people came to my field).

or to strangers (Gamble, 1955). When there is still an abundance of (fertile) land not claimed by anybody of the founding lineages, a stranger can clear as much land as he can farm, which then will be given to him. In the case that all land in a village is claimed but not used for farming, a stranger can clear the land he needs for farming. If the stranger decides to move out of the village with his family, the land is returned to the landowner. In areas where land is scarcer, like in Tujereng, strangers might need to go to different landowners every few years to borrow land. In such cases it can also happen that, just before the rainy season starts, the landowner tells the stranger that he actually wants to cultivate the plot of land he promised to the stranger. So, in areas where land is scarce, security of access to land is less for strangers and conflicts over land are more common.

Except in the rural areas near the urban areas in the western part of the country, access to land is not a big problem in most parts of The Gambia at the moment, but it might become one of the major issues in the coming 10-20 years because of the huge population increase. Land-owning families or clans with many male adolescents might need to split up their lands to be able to give each male a share. And although access to land is not yet a general problem, access to fertile land close to the compound is already a problem in densely populated areas.

In the past, it was common to give a plot of land for a symbolic amount of money or some kolanuts to a stranger to build his compound. Nowadays, however, it is common, particularly in the western part of the country, to sell the land instead of giving it away for kola. People also started to buy land for arable farming. This ensures them of access to land, but they need a lot of money to buy a sizeable area, which is not an option for many people. In the coastal areas two factors are driving up prices. Because of the favourable climatic conditions, Europeans like to settle in the coastal areas, increasing the prices for land. The other, possibly most important, factor is that Gambians who successfully migrated to the urban areas now prefer to buy and develop land in the nearby rural areas instead of developing land in their home villages up-country. This development will eventually lead to land owning and landless classes.

The above refers to the uplands. The *faro* (lowland) is a somewhat different story. In Mandinka culture, *faro* land is also predominantly owned by men, usually belonging to the founding families of the village, but used by women to grow rice and, in some cases, vegetables. If land is cleared by a woman (what is the case sometimes), that woman becomes the owner of that land. When that woman dies, the land is inherited by her sons, but not by her daughters (Gamble, 1955). Whether strangers have access to land depends on the availability of surplus land. After World War II, for example, when roads were constructed in the *faros* in LRD to open new lands for rice farming, strangers were also allowed to clear land, and consequently allowed to own land. If somebody clears unclaimed land, that person is entitled to own that area. This is also the reason why men still clear rice fields, although they leave all other work on rice to the women. In some villages *faro* is very scarce, while in other villages there is an abundance of *faro*, and both categories can be geographically right next to each other. In villages where *faro* is scarce, land is divided into small plots and distributed among the women of the founding families, who own the land. In the village of Tujereng, where *faro* is scarce, newcomers are not given any land in the *faro*, except it is lent for a few years in particular cases. In other places, like Faraba, it is not difficult for newcomers to get land in the *faro*. In Faraba, however, men often complain about the lack of nearby fertile lands in the uplands.

From the interviews it became clear that land ownership not only depends on the availability of land, but that more complicated social and cultural factors are involved. In the village of Jiroff, for example, Fula are the founders of the village and own the land, while most Mandinka, who settled in the village later, as strangers, do not own land, even though there is not a land shortage in the village. Therefore, Table 2.9 only shows the total figures for land ownership, for men and women (which in the case of women is actually usufruct rights, see above) and further subdivided for founders and strangers. Table 2.9 indicates that fewer women have rights to land than men and that more founders own land or have usufruct rights than strangers.

Table 2.9: Percentages of men who own land and women who have usufruct rights on land, divided into those born in the village (founders) and those recently settled in the village (strangers) (data from 2002-questionnaire).

	men			*women*		
	founders	stranger	average	founders	stranger	average
owns land[1)]	95.5	58.1	85.2	88.1	49.1	69.0

[1)] = usufruct rights in the case of women

2.3 Agro-ecological changes

Climatic changes

The Gambia is one of smallest countries of the African continent, comprising only 11,000 km^2 and flatter than The Netherlands. There are, however, clear climatic differences within The Gambia. The Gambia is associated with both the Western Sudan and coastal forest (Quinn, 1972). Average annual rainfall is about 600 mm in the North and about 1100 mm in the South-western tip (Figure 2.6).

Figure 2.5 shows rainfall in The Gambia has had a very irregular pattern over the past 115 years. Before the decrease in rainfall that started in 1968 rainfall was adequate for agriculture, except for the years 1913 and 1941 (Hutchinson, 1982). From 1968 onwards, rainfall decreased systematically, with the lowest record in 1983 (Figure 2.5). The past 10 years seem to show a slight, but irregular, increase in rainfall.

Both Nicholson (1978) and Brooks (1993) indicate that dry and wet periods alternated with each other in the past (Table 2.10), although there is some disagreement about the actual time pattern (Webb, 1995). The descriptions on changes in rainfall presented by Curtin (1975) agree with those given by Brooks (1993). The variation in rainfall is probably caused by the north-south movements of the inter-tropical convergence zone, which is partly influenced by the steepness of the arctic-to-tropics temperature gradient (Curtin, 1975). A cooling of the northern latitudes tends to push the inter-tropical convergence zone southwards, resulting in less rainfall in the Senegambian region. Based on this information, it is not a question of whether rainfall will improve in the future, but when it will improve.

The 1000-mm isohyet for wet periods runs north of The Gambia, whereas the 1000-mm isohyet for dry periods only touches the south-western tip of The Gambia (Figure 2.4). The 1000-mm isohyet can be used to indicate where upland rice cultivation is feasible and where not. According to Abifarin *et al.* (1972), upland (rain fed) rice needs about 60 mm of rain each 10 days. If taking into account that in The Gambia rainfall easily reaches 400 mm in August and 300 mm in July, annual rainfall needs to be at least 900 mm for a crop of early rice to mature in the uplands. This means that during the dry periods upland rice cultivation is possible in many parts of The Gambia, but just north of The Gambia, upland rice cultivation is only possible during the wet periods.

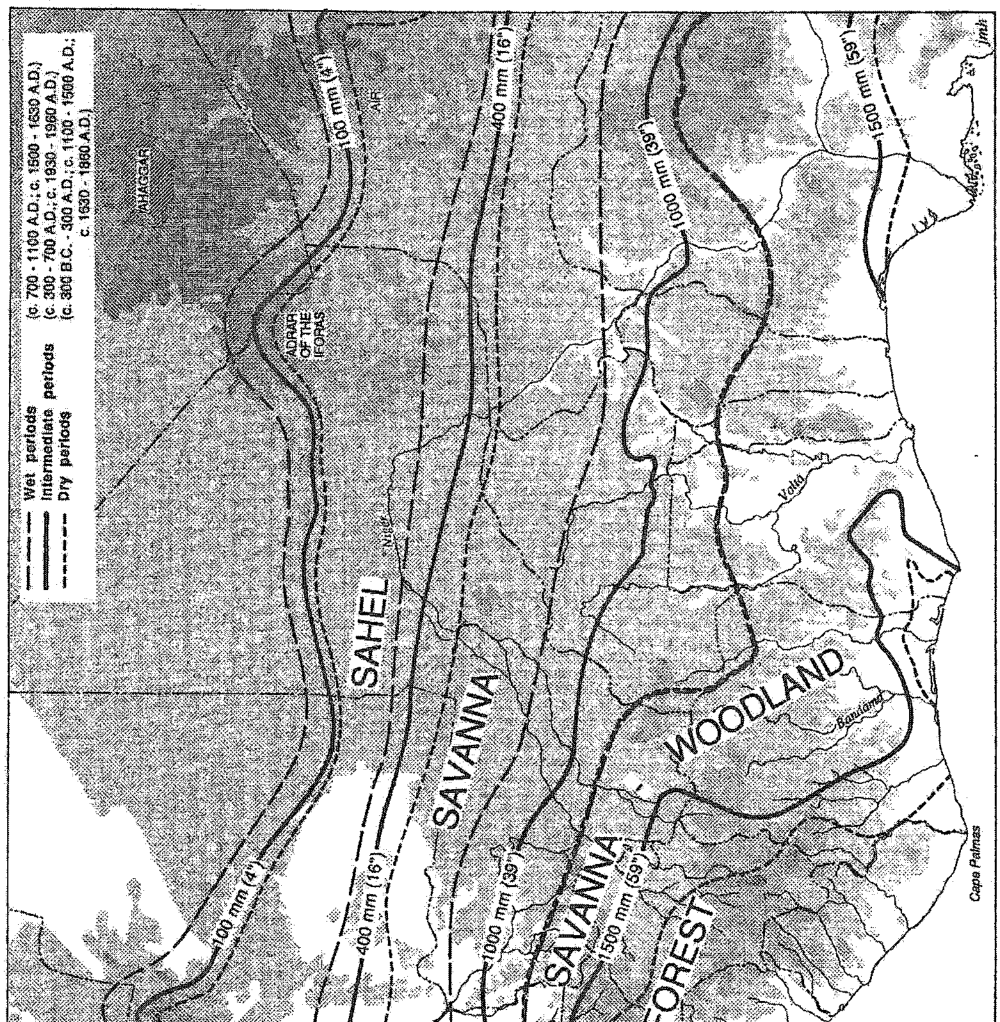

Figure 2.4: Rainfall patterns and ecological zones of West Africa (from Brooks, 1993)

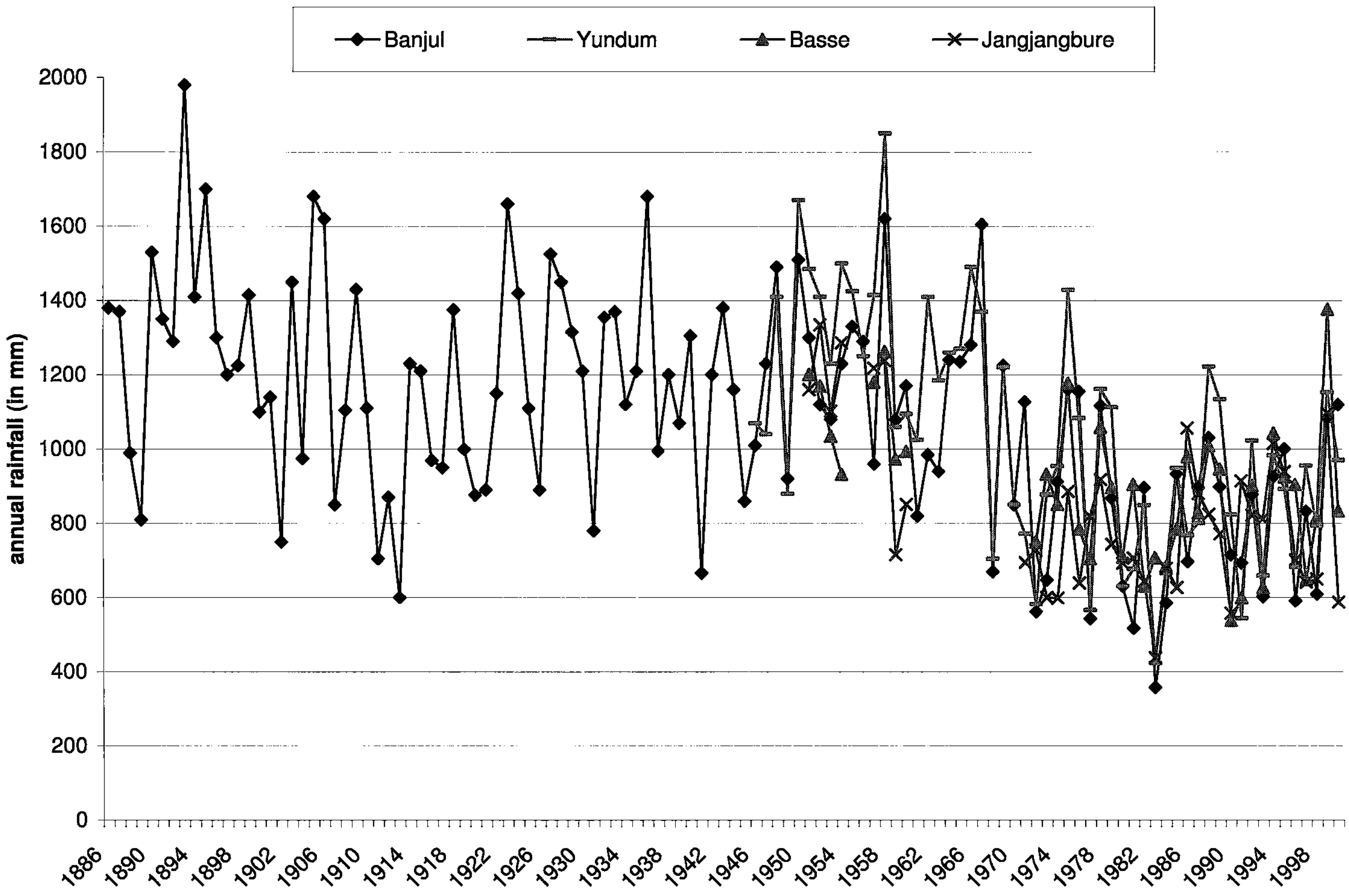

Figure 2.5: Annual rainfall pattern for four stations of The Gambia (combined data from Department of Hydrology, Banjul, 2003, and from Hutchinson, 1982).

The movements of the 1000 mm isohyet over time suggest that in the past people had to change varieties for upland cultivation whenever a dry period followed a wet period. Furthermore, climatic changes also must have had a huge impact on lowland cultivation, opening up new areas and making others unsuitable for rice cultivation. Because of the drought of 1983 almost all farmers replaced late millet with early millet in the northern areas (DOP, 1995).

Table 2.10: Changes in rainfall patterns in western Africa, from 1100 to the present (from Webb, 1995).

	Nicholson[1)]	Brooks (1993)
wet	c. 800 to c. 1300	
dry	c. 1300 to c. 1450	c. 100 to c. 1500
wet	late fifteenth to late eighteenth century	c. 1500 to c. 1630
dry	late eighteenth to late nineteenth century	c. 1630 to c. 1860
wet	late nineteenth century	c. 1860 to c. 1900
dry	late nineteenth century to the present	early 1900s
moderate		1930-60
sporadic drought		1960 to the present

[1)] Sources: Nicholson, A climatic chronology for Africa, esp. 75-81, 251-254, and 'Climatic variations in the Sahel, 3-24 (1978).

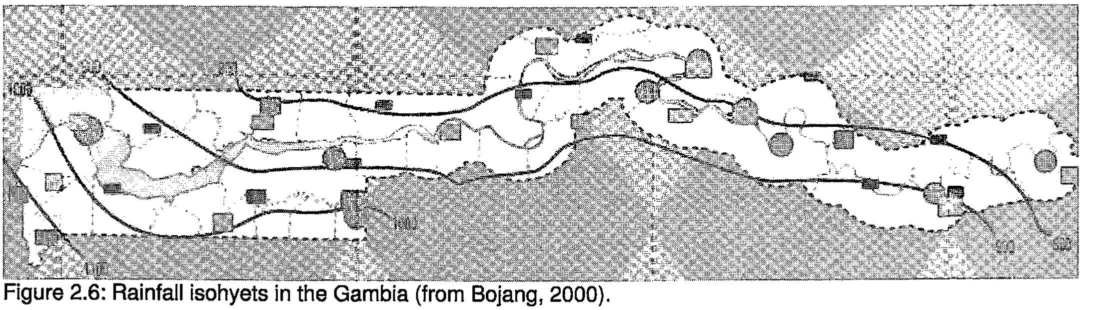

Figure 2.6: Rainfall isohyets in the Gambia (from Bojang, 2000).

Agro-ecological zones

In total, 6 agro-ecological zones (AEZ) are identified (Bojang, 2000), with their main characteristics presented in Table 2.11. Soils in The Gambia are relatively homogeneous, although variation at micro-level does exist (Dunsmore *et al.*, 1976). Therefore, rainfall is the main factor in the identification of the agro-ecological zones. Rainfall is lowest in the north-east and highest in the south-west (Figure 2.6). Rainfall starts first, in early June, in the east of The Gambia and commences in the western part of the country 2-3 weeks later (Table 2.11). Likewise, rains stop in the east at the end of September, while in the west rainfall often continues up to the middle of October. Maximum temperatures near the coast hardly go above 35° C, whereas they easily go above 40° C in the eastern interior.

Because of extensive deforestation, most parts of the country are today dominated by grasslands and shrubs. Extensive forests can only be found in the south-western part. Mann (1987) gives an estimate of the reduction in two-story forest from 28 percent of the total land area in 1946 to 3.4 percent in 1968 and of savanna woodland from 31 percent in 1946 to 4.6 percent in 1968. In the past 20 years, various projects have been started to replant trees, but whether these projects can effectively counter deforestation is not clear. Because of population increase, more land is needed for agriculture and more wood is needed for cooking and building. Nowadays, most of the firewood used in The Gambia comes from Casamance, and tree species suitable for timber do not grow in The Gambia anymore, or are protected and cannot be logged.

Because of irregular rainfall patterns and differences in occurrence of pests and diseases over the years, farmers grow a range of crops (Swindell, 1992). The main arable crops grown in The Gambia are groundnut, pearl millet (both early and late), rice, sorghum, and maize. Most main crops are grown in all agro-ecological zones (Table 2.11), although there are differences in scale. Groundnuts and maize are grown in all parts of the country. Rice is also common except in the eastern part (AEZ 6), whereas sorghum is less common in the western part. The various rice ecologies are described in depth in Chapter 3. Late millet is only grown in the southern part (AEZ 1 and 3), and in some parts of AEZ 6 in the east, where rainfall is 800 mm or more. Early millet is grown in the other areas (AEZ 2, 4, 5 and 6), where rainfall is less.

Table 2.11: Main characteristics of the agro-ecological zones of The Gambia (adapted from Bojang, 2000).

	area	rainfall (in mm)	first rains	crop season (in days)	main crops *)	dominant vegetation
AEZ 1	South-West	> 800	June 15-30	135	G, LM, M, R	grasslands and forests
AEZ 2	North-West	700-800	June 15-20	120-135	EM, G, M, R,	extensive grasslands with few interspersed trees
AEZ 3	South	800	after June 15	120-135	G, LM, M, R	extensive grasslands with shrubs and few trees
AEZ 4	Middle	650-750	before June 15	120-135	G, EM, M, R, S	Savannah with grasses and riparian forest
AEZ 5	North	600	June 1-15	< 120	G, EM, M, R, S	open Savannah with grasses and shrubs
AEZ 6	East	700-800	June 1-15	135	G, EM, LM, M, S	grasslands with scattered trees

*) G = groundnut, EM = early millet, LM = late millet, M = maize, R = rice, S = sorghum

Dynamics in crop choice

Figure 2.7 shows most land is used for groundnut cultivation, because it is the main cash crop. However, because of decreasing prices since the early 1970s, the area used for groundnut gradually decreased. Since 1998, farmers in the northern part of the country were able to sell their groundnut for better prices in Senegal (Manneh, personal communication) and total groundnut cultivation increased.

After World War II (likely also before WWII), farmers used *findo* (Mandinka for *Digitaria exilis*), early millet and upland rice to shorten or eliminate the hungry season, and used lowland rice and late millet as the main crop (Webb, 1992). With the decrease in rainfall in the early 1970, the decrease in labour due to schooling from the 1950s onwards and the increased availability of imported rice from 1970 onwards, the importance of these crops changed. In most parts of the country the majority of the farmers stopped growing *findo*; in the middle and eastern part of the country the importance of upland rice decreased; and in the southern part farmers stopped growing early millet. In Janack farmers said they stopped growing early millet when children went to school, resulting in a smaller labour force. Because early millet does not have bristles and millet is one of the preferred foods of birds (among which the social weaver bird (*Quelea quelea* L.) is the most notorious pest), children are necessary to scare away the birds.

Although quite uncommon in the early 1970s, the area for early millet expanded over the years, because of the reduced rainfall, and it seems as if the increase has not halted yet. Particularly farmers in the northern part of the country replaced late millet with early millet because of the decrease in rainfall. Another reason is that because of decreasing groundnut prices farmers allocate less land to groundnut and more to early millet. A third factor is the decrease of suitable rice lands, because of which women in some areas have changed to millet cultivation. A fourth factor may be population increase resulting in an increased labour force.

Maize also shows an increasing trend, while late millet and sorghum are rather stable in area. Although in the northern part of the country farmers stopped growing late millet, the total area for late millet remained stable over the years because farmers in the southern part increased the area cultivated with late millet due to falling groundnut prices and, possibly, population increase. Near the urban areas farmers gradually stop or decrease the cultivation of millet and groundnut. In Tujereng male farmers say they prefer to grow other, more profitable cash crops instead, like cassava, watermelon mango and oranges.

The area used for rice cultivation has decreased compared to the early 1980s, even though the Gambian government emphasises the importance of rice as the main staple crop of the country. From the 1970s until the present, government and NGOs continue to build roads to improve access to rice swamps and dikes to increase the areas for rice cultivation. From 1994 onwards, a slight increase of area is apparent, but it is not clear whether this is a temporary or a more permanent trend.

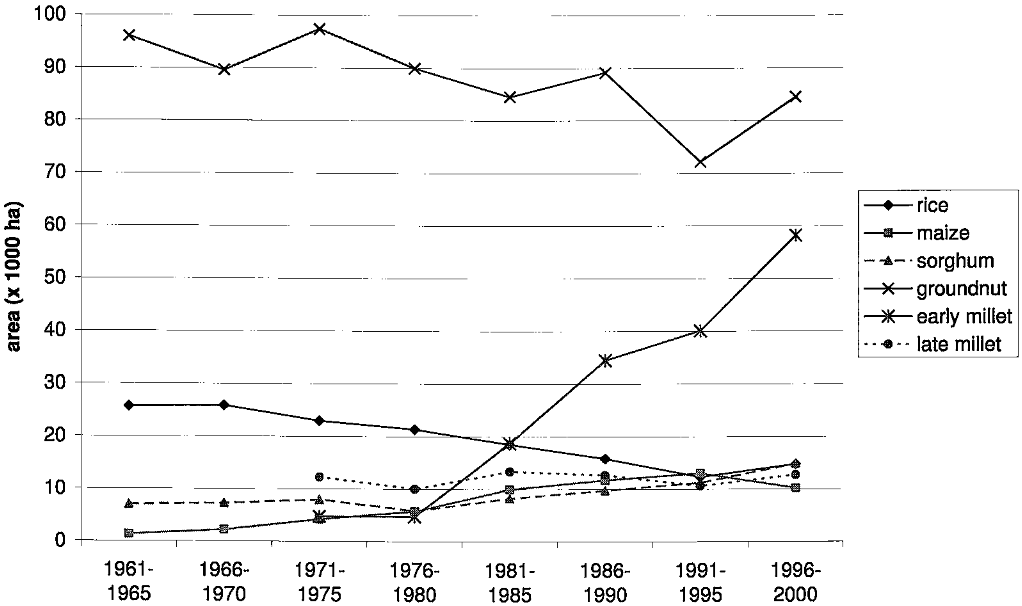

Figure 2.7: 5-year averages for cultivated area for rice, maize, sorghum, groundnut, early millet and late millet, from 1960 to 2000 (combined data from FAOSTAT database and DOP, 2002).

In the past (probably before 1970), *findo* cultivation was common but, nowadays, seems in sharp decline. No records have been kept about the area under *findo* cultivation for the past 15 years. In some areas *findo* cultivation remains quite common, however (Table 2.12). *Findo* (also called hungry rice) was regarded as food of the poor in the past, but nowadays has become food for the rich, too expensive for most people to buy.

There is no information collected by the Department of Planning on cash crops like cassava, watermelon, mango and oranges, but gradually these crops are gaining in importance and in cultivated area. Table 2.12 shows percentages of farmers growing these crops. In Kiang, particularly, only a few farmers grow cash crops like fruit trees, cassava and watermelon. All cereals are subsistence crops in the first place: millet, sorghum, maize, *findo* and, although not shown, also rice (Table 2.12). Maize, more than any of the other cereals, is also used as a cash crop. Crops like cowpea, sweet potato and sesame are used for both subsistence and income and are often grown in small fields.

Table 2.12: Percentages of men growing and selling various crops in different districts (data from 2002-questionnaire).

	men growing various crops (in%)				men selling crops (as percentages of # men growing particular crop)			
crop	Kombo	Foni	Kiang	Fuladu	Kombo	Foni	Kiang	Fuladu
late millet	93	100	-	100	0	0	-	10
early millet	-	-	100	-	-	-	0	-
maize	59	76	65	90	21	5	8	17
sorghum	16	48	10	75	0	0	0	7
findo	23	59	35	10	0	6	14	0
cassava	59	52	45	55	82	67	56	82
groundnut	73	86	90	75	95	92	100	100
water melon	32	24	5	50	72	100	100	80
cowpea	32	52	5	40	33	13	100	25
sweet potato	13	45	10	25	71	54	50	80
sesame	7	21	5	20	50	50	100	75
pumpkin	-	-	-	5	-	-	-	100
mango	77	72	55	85	72	76	27	65
orange	77	62	5	30	95	78	0	67
banana	39	48	10	10	86	79	100	100
cashew	41	24	5	5	61	14	0	100

Whereas crops like groundnut, rice, millet, and maize are commonly grown by almost all farmers in all villages, crops like sorghum, *findo*, watermelon and particular fruit trees are often only grown in particular villages. In Tujereng almost nobody grows *findo* nowadays, but it is quite common in Faraba and Janack. Watermelon is commonly grown in Tujereng and Sanending, but not in the other villages. In Foni sorghum is generally common, but there is considerable variation between villages.

In the villages near the urban areas millet cultivation is decreasing because of labour shortages and because it is a staple and not a cash crop. Because fewer farmers in Tujereng cultivate millet nowadays, their millet suffers more from birds, and some farmers changed to sorghum cultivation instead. Although sorghum does not taste as nice as millet, the advantages of sorghum are that it suffers less from birds and is easier to thresh than millet. Richer farmers, who can afford fences, changed to cassava farming. Cassava is a very profitable crop but, because it takes a whole year till harvest time, it needs a strong fence to protect it against cattle during the dry season.

Except for rice, all of the above mentioned crops are grown by men. On average, men grow 4.7 crops while women grow 1.5 crops (Table 2.13). Women primarily grow rice and in areas where rice can be cultivated it is rare for women not to be involved in rice farming. In those areas where women engage in rice farming women rarely grow other crops, except in Fuladu, where almost all women grow groundnuts. In Fuladu less area is suitable for rice cultivation than in other districts. In places where rice farming is not possible at all women mostly grow groundnuts and millet, and to a lesser extent vegetables and sesame. Other crops are less frequently grown by women. Women grow cereals, of which rice is by far the most important, for home consumption, while vegetables, groundnuts and produce of fruit trees are mostly sold.

Table 2.13: Average number of crops and fruit trees grown by men and women in the various districts, combined with the percentage of women who are involved in gardening (data from 2002-questionnaire).

district	*men* # crops	# fruit tree species	*women* # crops	# fruit tree species	% active in gardening
Kombo	4.2	2.4	1.4	0.6	90
Foni	5.6	2.1	1.5	0.4	40
Kiang	3.7	0.8	1.2	0.1	40
Fuladu	5.5	1.3	2.0	0.6	80
total	4.7	1.9	1.5	0.5	70

Men also grow more fruit tree species than women do. Fruit trees grown by men are often mangos and oranges, which are planted in the compound, and cashew planted as borders in the fields. Bananas, and to a lesser extent mangos and oranges, are planted by women in the lowlands. Women who are engaged in gardening often plant fruit trees. Hence, in Kiang where gardening is not common, very few women grow fruit trees.

Vegetable gardening is a typical woman's activity. Although a majority of interviewed women is involved in gardening, gardening is limited by the availability of suitable areas and water during the dry season. It is possible that one village has abundant land suitable for gardening, while a neighbouring village hardly has any suitable areas. In some villages, like Tujereng and Kitti, the same lowlands are used for rice growing in the rainy season and vegetable gardening in the dry season. In non-inundated areas women often intercrop rice with vegetables like okra, sorrel (hibiscus) and *kerenkerengo* (Mandinka name for a leafy vegetable) during the rainy season. In Jiroff and Massembe, near the river Gambia (where the river is salt for 6 months of the year), women are limited in gardening because of limited water supply. Because the rice fields are continuously flooded in these places, it is also not possible to intercrop rice with other vegetables.

Land use

Despite population growth from the 1950s, it seems total cultivated area increased only over the past 10 years. Figure 2.8 shows cultivated area per district over time as a percentage of available land for agriculture. The graph shows a clear increase in land use for NBD from the 1980s onwards, whereas no clear pattern is visible for the other districts. One reason for an increase in land use in NBD is that it is more mechanised than other parts of the country because of its proximity to northern Senegal, which is more mechanised than The Gambia (Baker, 1995). Another reason is that farmers in NBD benefit more from higher groundnut prices in nearby Senegal (Carney, 1993). In the other districts population increase may have been balanced by the decrease in number of strange farmers (farmers from outside Gambia who temporarily farm in The Gambia), increased numbers of children going to school, and young males migrating to the urban areas. This, in turn, might explain the stable pattern in land use. It is estimated that in the late 1940s strange farmers were responsible for one third of the annual groundnut crop (Webb, 1992). Migrant labour remained stable until at least 1966 (Webb, 1992). It is not clear when the number of strange farmers decreased, but most likely this began after the decline in rainfall in the 1970s and decrease in groundnut prices in the 1980s. Nowadays, strange farmers are no longer common (Baker, 1995). Table 2.1 shows the cultivated area per capita decreased from 0.90 ha/capita in 1960 to 0.43 ha/capita in 2000, but the strange farmers were not included in the number and thus not included in the calculations. Two other factors that, possibly, also contributed to the decrease in land use per capita are the decreases in rainfall and farming income, both having discouraging effects on farmers. Possibly, the improved rainfall from 1998 to 2001 and better groundnut prices in Senegal, in turn, might have had an encouraging effect on farmers in the past few years (Figure 2.8).

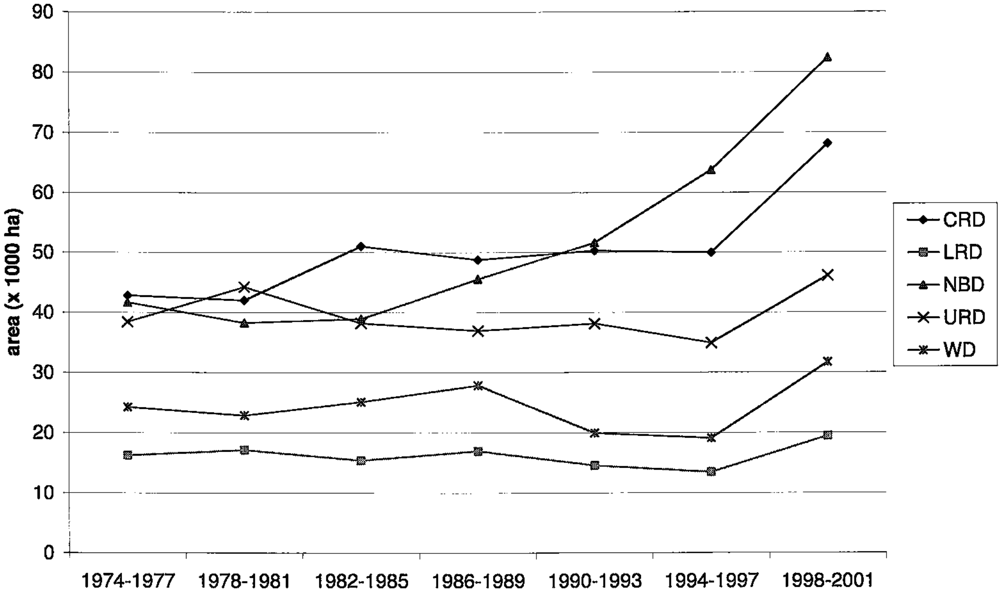

Figure 2.8: 4-yearly averages for cultivated area per division: CRD = Central River Division, LRD = Lower River Division, NBD = North Bank Division, Western River Division (data from DOP, 2002).

A different land use, for which no statistics exist, is the grazing of cattle. It may be assumed that with the population increase the number of cattle also increased. In the 1950s, ploughing with oxen was introduced (Weil, 1973) which also stimulated ownership of cattle. Although cattle provide manure, they are also a danger to crops and vegetables, when towards the end of the dry season grass in the bush is dry and limited in availability. As a consequence, gardening and cassava cultivation, which both take place during the dry season, are only possible if farmers have fences strong enough to keep out cattle. The introduction of schooling also means that fewer children are available to guard crops against cattle, birds and other pests, with the effect that the risk of crop failure due to cattle increases in fields further away from the compound. With the younger men looking for jobs outside agriculture, the bulk of the farming falls on the older men, who therefore prefer to work the fields closest to the village every year instead of rotating far and nearby fields (Baker, 1995).

Yield patterns

It is often stated that because of shortening fallow periods, land degradation and decrease in rainfall, yields have decreased (see Baker, 1995; Swindell, 1992; Marong *et al.*, 2001). Many farmers complain that in the past they had better harvests than nowadays. This is true for groundnut (Figure 2.9). All other crops, however, show trends of increasing yields. These trends are clearest for rice and maize, and the yield increases of these two crops are most likely due to the introduction of higher yielding varieties. Sorghum and millet, of which no higher yielding varieties were introduced, also show some slightly higher yields in the 1990s. Possibly the improvement in rainfall contributed to the yield increases in the 1990s.

According to Akinboade (1994), yields did not respond to agricultural policies, like subsidies on fertiliser, but remained stagnant. However, the yield increases in the early 1980s in Figure 2.9 can best be explained by increased fertiliser use. After the ERP (Economic Restructuring Program) in 1985, subsidies on fertiliser were reduced and fertiliser use decreased rapidly, which explains the decrease in yields in the late 1980s. How much fertiliser was actually used by farmers is difficult to estimate since a lot of fertiliser was re-exported to Senegal, and exact quantities of this re-export are not known (Jabara, 1990).

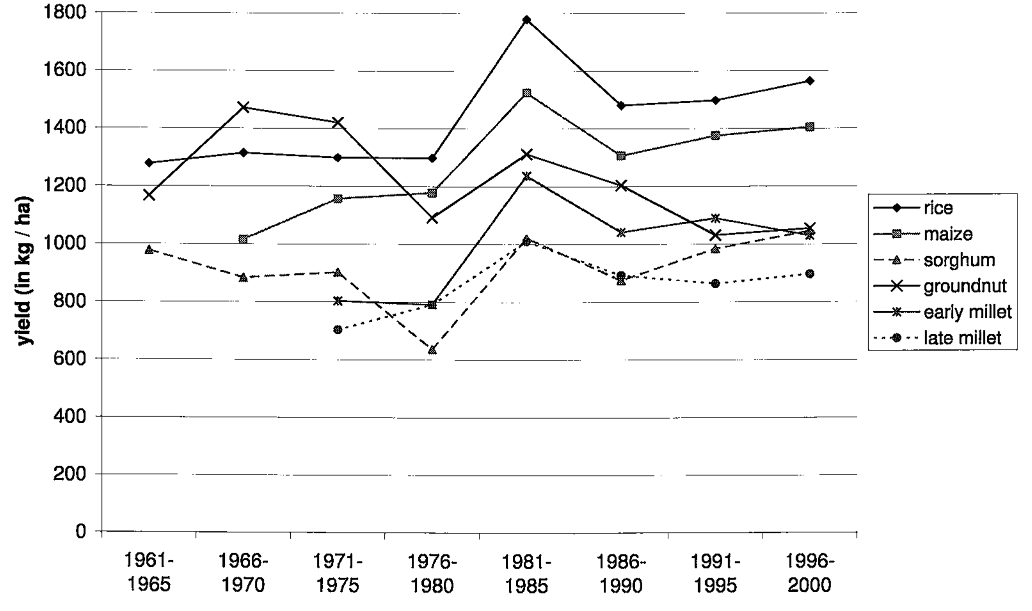

Figure 2.9: Five-year yield averages for rice, maize, sorghum groundnut, early millet and late millet from 1960 to 2000 (combined data from FAOSTAT database, 2004 and DOP, 2002).

Figure 2.8 shows that only in the northern part of the country was there much increase in cultivated area and rather little in the southern part. This indicates that in the southern part fallow periods cannot have shortened much over the past 40 years. But also for NBD, where total cultivated area has increased the most, no decline in yield is apparent (data not shown). If yield is taken as measurement for the level of adaptation of farming systems, this might mean that the Gambian farming system is more adaptable than generally assumed. Rasmussen (1999) argues that land degradation does not necessarily lead to reduced production capacity and that a lot is unknown about the stability and resilience of ecosystems.

The only crop which shows a declining trend in yield is groundnut (Figure 2.9). One explanation could be that groundnut is more susceptible to soil degradation than the other crops. Another explanation is that because of lower prices, from the 1970s onwards, farmers were discouraged in groundnut farming. Whereas all other crops show a clear peak from 1980 to 1985, the peak for groundnut yield is less clear.

So, it seems that the perceptions about declining yields can only be explained by the fact that in the 1980s, when fertiliser was available, farmers were able to achieve high yields, while in the 1990s they had far less access to fertiliser, and consequently yields dropped to a lower level compared to the yields of the 1980s, but they were still higher than the yields of the 1970s and even 1960s, when rainfall was far higher than in the 1990s. We need also take account of a 'general' perception that things were better in the past.

2.4 Summary: The relevance of agricultural dynamics for seed systems

In recent times, The Gambia has experienced many agricultural changes, varying in impact and intensity. Probably the biggest impact can be attributed to the decrease in rainfall in the early 1970s, when farmers regularly experienced crop failures. With the decrease in rainfall, rice imports increased and farmers had to change varieties of rice and millet (for more details on the latter, see Chapter 5). Other important changes include the decline in groundnut prices in the 1980s. More gradual changes are the improvement of infrastructure and schooling, which started in the 1950s. Colonial government policies aimed at increasing groundnut production, begun in the 19th century, but after World War II, the emphasis shifted to increased food production, in particular that of rice.

Considering the yield levels of various crops over the past 40 years, the Gambian farming system is quite robust and possibly more resilient than generally assumed. However, it might also be possible to consider this robustness a concurrence of and interaction between a number of factors, in particular international and national markets, ecological conditions, government policies and demographic factors.

With an increased demand for groundnuts in the early 19th century, farmers were quick to expand groundnut cultivation. Where both men and women cultivated rice once, after 1850 rice cultivation became the sole responsibility of women (Watts, 1993). Because of the profitability of groundnut production, men decreased millet cultivation, which needed to be compensated by rice cultivation by women. An indirect effect was that rice became non-commoditised (i.e. it became solely a subsistence crop). Gradually, Gambian farming became increasingly commercialised (Haswell, 1991).

From the 1950s onwards, infrastructure gradually improved and particularly young men (very important as labour for farming) migrated to the urban areas. More schools were built and children were no longer available to help with bird scaring and harvesting. By themselves, these developments did not seem to have major effects. This was in part because after 1950, the population boomed and a swollen rural population mitigated the impact of schooling and decreasing groundnut prices on labour supply). Rural populations expanded at a slower pace compared to urban populations, with the result that land pressure was slow to appear and has become apparent only in the past 10 years.

Because of climatic, economic and social changes, farmers have changed the area they allocate to the various crops, but have not changed their portfolio of crops that much. Farmers still grow a wide range of crops, which serves as a buffer against droughts and other adversities. The only crop that clearly decreased in area is *findo*. With the decrease in rainfall in the 1970s, rice production decreased and large quantities of rice were imported and became more popular as taste improved. The combination of less available labour and a better tasting imported rice seems to have been a factor in farmers abandoning hungry season crops like *findo*, a crop difficult to process.

With the opening up of new riverine rice lands in the 1950s, increased rice production enabled women to become more economically independent from men (Weil, 1973; Webb, 1992). When rainfall decreased in the 1970s, suitable areas for rice farming diminished and various NGOs helped women in the 1970s and 1980s to commercialise vegetable gardening. With the commercialisation of vegetable gardening, the economic independence of women was further improved. Nowadays, vegetable gardens are an important source of income for women and sometimes even for their husbands (Schroeder, 1997b).

From the late 1970s onwards, government tried to stimulate farming through extension and subsidised inputs like fertiliser. When in the 1980s groundnut prices collapsed, the government had to restructure its financial policies, with the consequences that many extension officers were retrenched and subsidies on fertiliser were abolished. In combination with decreasing groundnut prices, many farmers were discouraged from farming. However, in the northern part of the country farmers were able to mechanise groundnut cultivation and in the coastal areas farmers switched to the cultivation of other cash crops like cassava and watermelon. For these crops farmers often hire tractors for ploughing and buy fertiliser.

Because of the irregularity in rainfall and low prices of other crops, it seems farmers are not willing to invest much in inputs like fertiliser, without which yield increases are not possible for rice and millet. Although calculations suggest that the use of fertiliser is economically profitable at current fertiliser and crop prices, farmers' perceptions are that fertiliser and other inputs are too expensive for these crops.

Nowadays, the younger generation tries to find a future outside agriculture, which is very difficult because of lack of alternative employment. Schooling did not enthuse the youth to build up a life in farming. Agriculture itself, however, still provides several alternatives for farmers to increase their income. Crops like cassava and fruit trees like mango and orange are very profitable, particularly because they require little labour. The disadvantage of these crops is they require strong fencing for protection against cattle during the dry season, which not all farmers can afford. Another alternative to groundnuts is watermelon which needs inputs like fertiliser and pesticides for a good production. Even *findo*, once a poor man's food, might prove to have renewed life as a speciality crop for wealthier urban consumers. Gradually, two groups of farmers will develop: those who have resources and can pay hired labour, and those who lack resources and who will work for the first group.

2.5 Conclusions: Impact of agricultural dynamics on seed flow and pollen flow

Agricultural dynamics has an impact on seed and pollen flow, the subject of the present thesis. In the areas where rice cultivation is possible, groundnut served as a vehicle for men to push rice cultivation into the women's domain and exert control over other crops. An indirect effect is that, nowadays, seed flows of rice move predominantly through female networks, and seed flows of millet move mainly through male networks. Another effect is that the labour organisation of rice and millet cultivation are organised through *sinkiroo* and *dabadaa* (female and male working groups) respectively, which influences harvesting and storage of rice and millet in different ways. Since adult women work together in *kafo* on rice fields whereas adult men do not for millet, different forms of shared knowledge concerning varieties are likely to emerge for rice and millet.

The decrease in rainfall had a big impact on variety choice for both rice and millet. In Chapter 5, two cases will be given, one of a village that was able to adapt to the changed conditions very well, and the other of a village that on its own was not able to match its rice portfolio to the changed ecological conditions. Before World War II, many farmers also used to grow both early and late millet. But, because of the decreased rainfall, farmers in the northern part of The Gambia continued working only with early millet. The decreased availability of labour has also had a negative effect on variety choice for millet in the southern part of The Gambia. There, farmers had to opt for late millet due to lack of labour, necessary for bird scaring in early millet.

With a better rice price / fertiliser price ratio, farmers may be more encouraged to use fertiliser, which in turn might stimulate them to engage more actively in farming and indirectly in seed exchange and thus gene flow. Fertiliser usage is also likely to affect farmer variety choices (it then makes sense to choose for fertiliser responsive varieties).

In the past, climate and availability of labour have fluctuated, and farmers have adapted by changing their variety and crop portfolios. The changes in variety portfolio have also changed the content of pollen flow, but not necessarily the effect of pollen flow.

Migration and trade lead to extended networks and exchange of seed over larger distances. However, after 1850, when groundnut trade boomed, rice became de-commoditised, and we may suspect that trade, in the last 150 years, has been a less important channel for seed flow in rice than once it was. However, improved infrastructure and increased rural population both tended to increase seed flow for both crops. In effect, although agriculture is more sedentary than in the past, farmers have more opportunities to move around and foster social contacts. Migratory movements (including return visits) by family members to the village) may now be a more important channel of seed flow, for both rice and millet, than trade. The remainder of this thesis will throw light on many of the micro-level processes of gene flow and management. Some of these regional – macro-level – tendencies are as yet inaccessible to investigate due to lack of adequate historical data.

3 Cultivation methods of rice and millet

3.1 Introduction

In the previous chapter Gambian agriculture was discussed in general. This chapter describes the cultivation of rice by women and millet by men, from field preparation up to storage. The primary aim of the information in this chapter is to explore which cultivation practices function as selection pressures, or induce divergent selection pressures or give us indirect information about farmer seed management. The information in this chapter will be particularly linked to the discussion in Chapter 4 on selection pressures. Seed selection will also be described in Chapter 4. Secondly, this chapter provides basic information on cultivation practices in The Gambia. In the discussion the main differences in cultivation methods for rice and millet will be highlighted. Furthermore, the main constraints for rice and millet cultivation will be described. The information in this chapter is based on a questionnaire conducted in 2002 and informal interviews and observations from 2000 to 2003, mostly in Tujereng. In the following text rice cultivation will be described first and millet cultivation second.

3.2 Rice

Ecologies and land use

Rice is grown under many different ecological conditions. The main division is between upland and lowland, which, in the Mandinka language, are called '*tandako*' and '*faro*' respectively. In the uplands a forested area is slashed and burned to make it suitable for rice cultivation. Palm trees, big trees and trees with use value are usually protected. Upland areas have sandy soils and rice can be grown for one or two seasons, after which a fallow period is needed of 10 to 20 years. Because of the decline in rainfall, *tandako* is limited to the South-western part of the country where rainfall is more reliable and is still sufficient for upland rice cultivation.

The lowland areas can be differentiated into three main types, which have in common that soils are often clayey, relatively fertile and high in water retaining capacity. For this reason continuous cultivation is possible and fallow periods are generally not necessary. The lowland areas can be differentiated into:

1. Irrigated lowlands, where rice cultivation during the dry season is also possible. The irrigated lowlands can be found in the eastern part of the country, west of Bansang. This ecology is not part of this study.
2. Mangrove associated lowlands, which can be found mostly along the river Gambia, which is part of the year salt, and part of the year fresh (see also Figure 3.4). At the beginning of the rainy season (end of June) the swamps are salty, and towards the end of the rainy season (early October) the salt is washed from the soil. At this stage, women transplant their rice, and in January-February, as the salt water is coming back again, the rice ripens and can be harvested. In the past, it was also common to cultivate the (rain-fed) areas just outside the swamps (in Mandinka called banta*faro* = outside the swamp), but because of the decline in rainfall these areas are not commonly cultivated anymore (Figure 3.1).
3. Fresh water swamps, which can be divided into river-fed and rain-fed lowlands, but in certain cases this distinction is difficult to make. River-fed lowlands are found mostly in the eastern part of the country where the river Gambia is not salty, while the rain-fed lowlands are found mostly in the western part of the country in so-called 'inland valleys' (Figure 3.2). Both river-fed and rain-fed lowlands can be divided into the typical lowlands, which are inundated (either temporarily or constantly), and the lowlands where often no water is

standing. The latter is also called the transitional zones because it forms a transition between the typical lowland and the typical upland areas. Because the geographical position, soil and land tenure system of the transitional zones are more similar to that of the typical lowlands than to the uplands, the transitional zones are normally grouped with the lowlands. Farmers call the transitional zones *faro* (meaning swamp in Mandinka), just like they call the typical lowlands *faro*, but a more correct name for the transitional zone is *bantafaro*. To explain among themselves which *faro* they mean, women often add a few words to '*faro*' to indicate the location of the *faro*. Because both transitional zones and flooded lowland are called *faro*, confusion can easily arise when farmers say that a particular variety can be grown in both *faro* and *tandako*. Varieties grown in the transitional zone are often short duration varieties that are also grown in *tandako*.

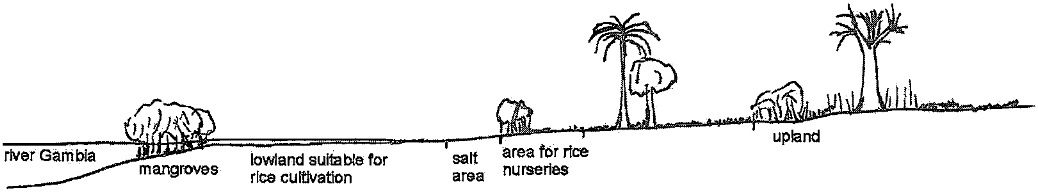

Figure 3.1: Schematic view of the associated mangrove ecology.

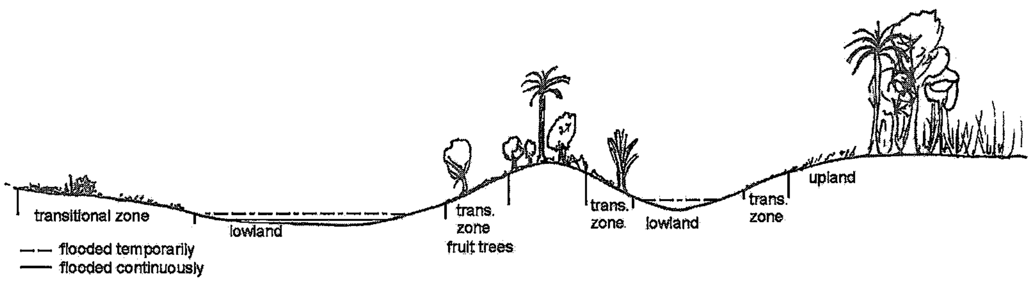

Figure 3.2: Schematic view of an inland valley swamp (difference in altitude between lowlands and uplands is usually less than 5 m).

Because of the limited extent of the fresh water swamps, it is common to find all rice fields close to each other, which in turn also makes bird scaring easier. In the mangrove swamp ecology, where more land is available, it is the difficulty of walking to and from, and within, the fields that induces people to make their fields close to the village and, hence, close to each other. For the uplands, effective bird scaring is the reason that women work fields side by side.

It is because long duration (higher yielding) varieties can be grown there, that farmers prefer the flooded lowlands to the uplands or the transitional zone. In villages where flooded lowlands are scarce only the women of the founding lineages can have access to these lowlands. Furthermore, because many people want to have access, these lowlands are often subdivided into very small fields (sometimes only 10 m by 20 m). In areas where lowlands are not scarce, land is also given to strangers and fields are much bigger. Hence, it is possible that in one village only members of founding lineages own fields in a *faro*, while in a neighbouring village also strangers have fields in a *faro*.

In villages with limited lowlands land ownership is not the only decisive factor whether women grow rice in the *faro* or not. Labour availability and compound composition are other factors. In Tujereng *faro* is limited but *tandako* is abundant. Since the decrease in rainfall in the early 1970s, the 'old *faros*' in Figure 3.3 are no longer flooded and are not suitable anymore to grow long duration varieties. Nowadays, only the 'main *faro*' (Figure 3.3) is suited for long duration varieties. Some women who have time and labour available prefer to grow rice in both *faro* and *tandako*. Women with limited amounts of time need to choose between *tandako* and *faro*. The advantage of the *faro* is the higher yield per area, but the plots are small. The advantage of the *tandako* is that the size is limited only by the bush that needs to be cleared, a laborious job done by men (usually the husband and relatives or friends of the woman). This means that a larger harvest can be obtained from *tandako* than from *faro* because of the larger area available in *tandako*. Hence, a larger *tandako* farm can be a better option for some women, even though they have their own *faro*. If a woman cannot find any men to clear the land, she can choose a 'second-hand' *tandako*: This is *tandako* which is abandoned by other women who have moved to a fresh piece of *tandako*. The disadvantage of 'second-hand' *tandako* is that it is very weedy compared to newly cleared bush. Women who are getting old and who do not have anybody to help them might choose to cultivate rice in the *faro* because of smaller size, which they can manage more easily than a big *tandako*. For the same reason, young women who do not have anybody in the compound to help with household work might also choose to cultivate rice in the *faro* only.

The *faro* of those women who prefer to work in the *tandako* instead of their own *faro* are usually lent to women belonging to the founding lineages who already have their own *faro*, or to strangers who have spent a long time in the village and enjoy good contacts with women with *faro* to lend. Those women who have moved to Tujereng recently usually only have the option to work in a *tandako*. Strangers without chances to ask men to clear bush for them depend on the availability of 'second-hand' *tandako*. If such a stranger is also the only adult woman in the compound, the chances of crop failure are big (if she falls ill, for example).

The number and types of ecologies farmers can use for rice cultivation and gardening differ per village, depending on local geographical conditions. Kitti has inland valley swamps and a very high water table, which makes the swamps very suitable for rice farming during the rainy season and gardening during the dry season, like in Tujereng. In Faraba, where rice cultivation takes place near the river which is salty during the dry season, gardening is done in a different part of the village. In Janack the water table is very low during the dry season and gardening is very limited.

Finally, rainfall is an unpredictable factor (See Chapter 2), which can force women to change their practices from one year to the other. Because of extremely high rainfall in 1999, too much water was still standing in certain parts of the *faro* in Tujereng for rice cultivation to be possible in the rainy season of 2000. Those women whose plots were flooded either had to grow rice in the *tandako* or to stop growing rice for a year or two. Only very few women opted for the second option. This situation above is primarily based on information from Tujereng. The situation may have differed in other villages.

Sowing

For the *tandako* and transitional zones it is important to sow the rice very early, after the first rains, because the rains at the end of the rainy season can be very erratic. Farmers need to avoid a situation in which rain stops during the grain-filling stage. In the lowlands, where rice is transplanted, the time window for sowing and transplanting is somewhat wider. In the uplands in Tujereng some farmers are able to sow early, at the beginning of July, while others only finish sowing at the end of July. Farmers who cultivate both *tandako* and *faro* sow the *tandako* first and the *faro* second.

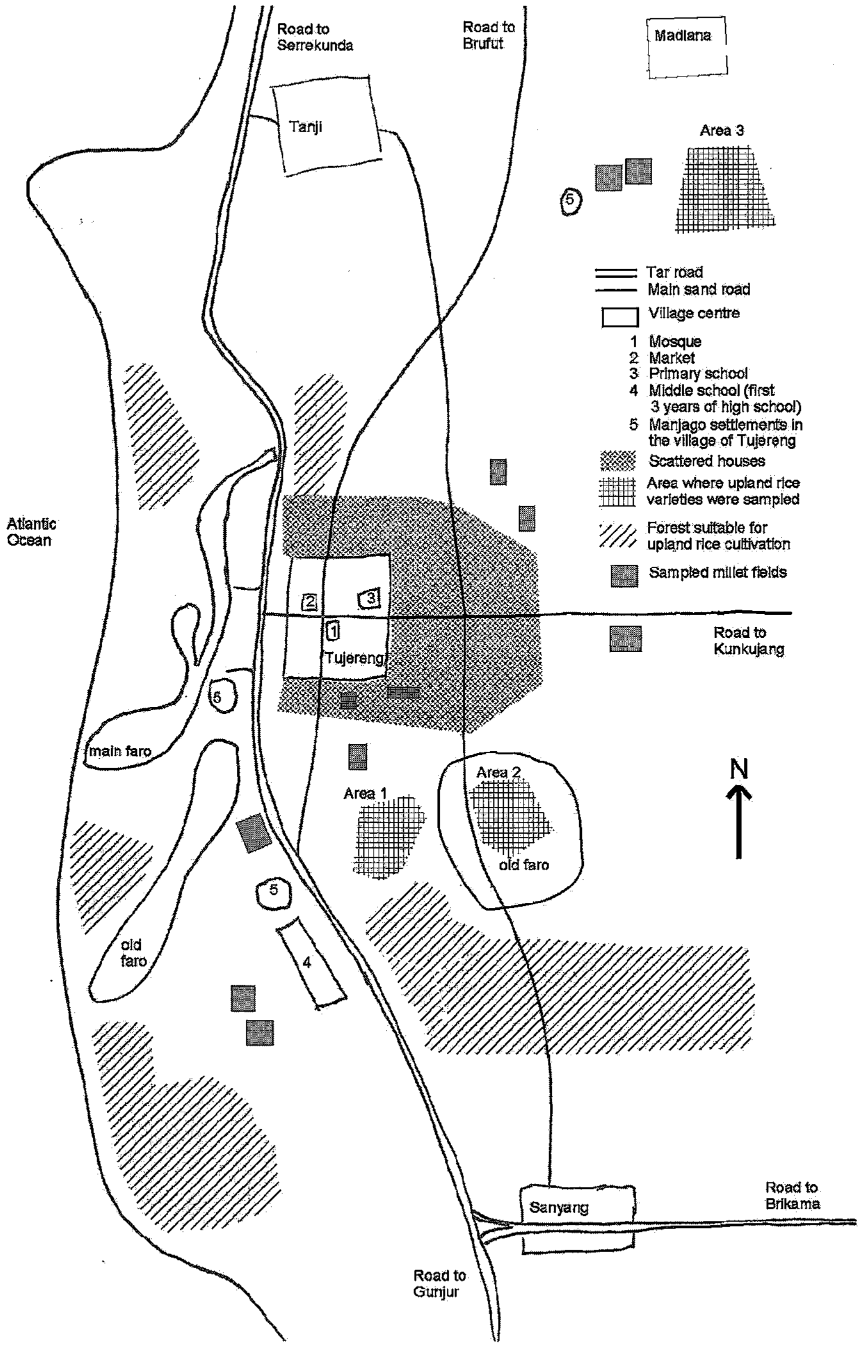

Figure 3.3: Schematic view of rice growing areas and sampled millet fields in Tujereng in relation to the surrounding villages (the map is not to scale: Tujereng – Tanji is about 5 km and Tujereng – Sanyang is about 7 km).

In Tujereng only a few farmers transplant their rice. Those who do transplant have plots in particular parts of the *faro* in which the water level can rise suddenly. In most parts of the *faro* this is not the case and it is also never certain whether they will be flooded or not. In villages like Faraba and Kitti, where the chances of sudden flooding are higher, a larger area of the *faro* is transplanted. In these villages much of the direct seeded rice is sown on ridges, to prevent submergence through sudden flooding. Such ridges are also used in Tujereng, but far less often. The disadvantage of sowing on ridges is that the soil needs to be moist for turning, which can mean a delay in sowing. In 2002, rainfall was erratic until the middle of the rainy season and many fields in Faraba and Kitti could not be ploughed and were left unsown.

Field size

Field size differs between villages, in relation to local ecological conditions, available area, number of people dependent on that area and labour availability. In many cases, fresh water swamps where rice is transplanted are limited in size, whereas associated mangrove swamps have no limitations on land availability (Table 3.1). As was mentioned in Chapter 2, field size in the associated mangrove ecology is primarily determined by labour availability. Hence, the information on Jiroff and Massembe suggests that a single farmer can work 0.5 up to 0.8 ha of lowland rice (Table 3.1).

The availability of transitional zones and upland areas differ per village. In Damphakunda and Sangajor farmers have big fields, while in Janack fields are much smaller. In Tujereng the fields in the uplands are relatively small compared to those in Janack, because of lower labour availability and higher average age of the farmers in Tujereng.

Table 3.1: Average size of rice fields and cultivated rice area per farmer for the various villages, which are grouped according to ecologies (data from 2002-questionnaire).

village	ecology [1)]	respondents (N)	average size (in ha)	std. deviation	area worked in ha / person
Jiroff	mangrove	10	1.4	0.99	0.53
Massembe	mangrove	9	1.6	0.84	0.81
Batabut	lowland	9	0.6	0.49	0.36
Kartung	lowland	7	0.5	0.21	0.29
Sanending	lowland	9	0.3	0.16	0.22
Faraba	lowland + trans. zone	16	0.7	0.43	0.20
Kitti	lowland + trans. zone	18	0.8	0.79	0.28
Damphakunda	trans. zone	9	1.3	0.98	0.39
Sangajor	trans. zone	10	1.2	0.74	0.85
Janack	upland / trans. zone	9	0.6	0.37	0.25
Tujereng	upland / trans. zone / lowland	18	0.4	0.23	0.15
total		124	0.8	0.73	0.36

[1)] = most common ecology in the particular villages; + = many farmers work in both ecologies; / = farmers grow in either one ecology. Except in Tujereng, lowland rice is mostly transplanted, whereas in the transitional zone (trans. zone), rice is mostly broadcast.

Weeding

In the uplands weeding is done, literally, by hand, i.e. the weeds are grasped one by one by the stem and pulled up. This is a very tedious and labour demanding job and during interviews many farmers asked for herbicides. In 1995, farmers were given herbicides by agricultural extension but, nowadays, few people actually use herbicides because of variable results and high costs. In newly cleared *tandako* weeds are not such big problem, so long as the weeding is done in time. Because of social events (e.g. funerals, weddings, etc) in the village, it may happen that a woman cannot weed for a week, and when she comes back to the field, she finds it completely overgrown. When that happens, weeding becomes very tedious and time demanding. Some fields even remain even incompletely weeded at harvesting time. In a second-year *tandako* weeds are a big problem immediately after the germination of the rice. NGOs and extension workers explained to women that sowing in rows makes weeding fast and easy, but in most cases women reverted to, or continued with, broadcast sowing. Compared to row seeding, broadcasting takes little time, and allows women to work independently from the men who own the donkeys needed for row seeding, and who are often reluctant to help the women.

Faro has the advantage that when it is flooded with water weeding is unnecessary. If rice is transplanted, weeding is only important in the nursery. In a village like Tujereng, however, it takes some time before the whole *faro* is flooded, if it gets flooded at all, and usually one, and sometimes two, weeding are necessary. An extra problem in the *faro* is wild rice (both annual and perennial), which is only distinguishable from cultivated rice to the practised eye at the vegetative stage. If not properly weeded, wild rice shades the cultivated rice because it elongates earlier.

Soil fertility

As part of this research soil analysis was conducted in four villages (Tujereng, Faraba, Kitti and Janack) to know whether there are any differences in soil characteristics between the rice fields of these villages, and to understand whether these differences might influence farmer variety choices, or exert a divergent selection pressure (see Chapters 4 and 10). In all four villages rice fields in the transitional zone were sampled, and in Tujereng and Janack upland rice fields were also sampled. Results show only small differences between villages (Table 3.2). The soils of the transitional zone in Janack and Faraba tend to have a more loamy texture than the other areas. The pH in Faraba and Kitti is significantly lower than in Tujereng and Janack. In all four villages, soil fertility is relatively low. The transitional zones in Tujereng and Janack tend to have lower phosphorus contents than in the other villages, probably because they are scarce and more frequently cultivated.

Table 3.2: Soil analysis data of rice fields (uplands and transitional zone) in 4 villages in Western Division (samples were taken in the fields of farmers interviewed in 2000).

village	ecology	# fields	sand %	clay %	silt %	pH water	avl. P (ppm)	N (%)	org. mat. %	EC[1] mmhos/cm
Tujereng	trans zone	5	54	17	29	5.3	2.7	8.0	1.9	0.056
Kitti	trans zone	4	57	14	29	3.9	5.5	8.0	1.4	0.043
Faraba	trans zone	3	45	22	33	4.2	7.0	9.3	2.0	0.043
Janack	trans zone	3	47	16	37	5.3	2.5	7.3	1.5	0.067
Tujereng	upland	6	56	18	26	5.7	5.1	8.3	1.8	0.065
Janack	upland	3	58	14	28	5.8	5.8	6.0	1.5	0.063
total	trans zone	15	52	17	32	4.7	4.3	8.1	1.7	0.052
total	upland	9	57	17	26	5.7	5.3	7.6	1.7	0.064

[1] Electrical Conductivity

Pests and diseases

In the coastal area, including Tujereng, birds are more numerous compared to the interior. To keep the 'bird pressure' low at ripening stage, farmers need to use varieties with similar growth periods and need to sow/plant their rice within the same time frame. Fields that are sown or planted too early will be excessively visited by birds. The worst bird is the social weaverbird (*Quelea quelea* L.), because it operates in hundreds, while other birds operate solitarily or in small groups. When rice matures in the *tandako*, women need to be in their fields every day, from 7 in the morning till 7 in the evening, for 6-7 weeks. Farmers in Tujereng growing *tandako* rice also asked many times about technologies to make bird-scaring more effective and easier. Rice in the *tandako* ripens mid-October and birds begin to visit the rice fields at the beginning of October. Towards the end of November particular grasses (related to millet) ripen, and the birds leave the rice fields. In addition, millet ripens in the second half of November and is preferred by the birds to rice. Consequently, women who grow rice in the *faro* in Tujereng, grow late maturing varieties which only ripen when the social weaver birds have found other food sources. This means that women growing rice in the *faro* do not need to do bird scaring at all. Early maturing varieties sown in the *faro*, however, are completely destroyed, unless intensive bird scaring is carried out.

In other villages birds are fewer and bird scaring is often not necessary. In Faraba bird scaring is only necessary when women sow rice varieties which are earlier than other varieties. In Kitti, only 20 km from Tujereng, women can sow varieties with different durations in adjacent plots in the same *faro*, without suffering serious damage.

Cows can be a terrible pest in the *faro*. Because *faro* rice stays green for the first months of the dry season, it is a welcome change of diet to the dry upland grasses for cattle. This means that the women have to harvest their rice as quickly as possible and avoid late sowing or very late maturing varieties. In the uplands cattle can also cause serious damage during the rainy season, when herdsmen, by law, should keep cattle away from crops. The cattle owners are often rich and influential, and only a few women would dare to start a court case against them.

Particular varieties are susceptible to various insects and diseases. It might be that insect pests cause more damage in the lowlands than in the uplands, but no detailed information is available. A few upland varieties are susceptible to termites. Farmers do not consider diseases a big problem. Certain fungi, like blast, are more prevalent in various areas across the country.

Inputs

The most common input women use is chemical fertiliser. Most women use it at an irregular basis (Table 3.3). When asking about quantities used, some women described the quantities in cups, which indicates that fertiliser is applied in small quantities. Because fertiliser is sold in cups, costing only a few Dalasi per cup, many women are able to buy small amounts of fertiliser. Differences between ecologies are relatively small, although in the transplanted *faro* chemical fertiliser is used less (Table 3.3). Women say that in a 'fresh' *tandako* you do not need to apply fertiliser, but you should apply it in the second year to maintain soil fertility.

Other inputs, like cow dung, insecticides and herbicides are not often used by women. Although many women own cattle (in small numbers though), they are not able to fertilise their field with cow dung[5]. Women know about insecticides and herbicides, but say they do not have the money to buy these. There is a strong correlation between the use of cow dung, insecticide and herbicide, which suggests that only well-resourced women have access to these inputs.

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[5] Normally, manuring is done by stationing a cattle herd in a plot during the night for a couple of weeks. Every couple of weeks the herd is shifted to another part of the plot.

Table 3.3: Use of inputs in various rice ecologies, in percentages of farmers per category (data from 2002-questionnaire).

input		*tandako*	fs *faro*[1)]	fs + fp *faro*	fp *faro*	fm *faro*	total
	respondents (N)	18	37	26	20	20	121
chem. fertilizer	every year	18	27	27	7	5	17
	irregular	39	49	50	30	70	45
	never	39	24	23	63	25	38
cow dung	every year	11	16	4	4	0	9
	irregular	6	3	8	0	5	5
	never	83	81	88	96	95	88

[1)] fs *faro* = farmers who broadcast rice; fs+p *faro* = farmers who broadcast and transplant rice; fp *faro* = farmers who transplant rice; fm *faro* = farmers who transplant rice in associated mangrove lowland

Harvesting

Harvesting is done by hand, using a small knife. In some areas extension workers tried to introduce sickle harvesting to make harvesting quicker, but so far, have had little success. Women often said that panicle harvesting is meant for women and sickle harvesting for men. In Tujereng some women know that in Casamance (in South Senegal) women use a sickle to harvest short stature varieties, but they say that they will not adopt sickle harvesting because they are not used to it. A variety called *Peking* is so short it is very difficult to harvest with a knife, and some women ask Manjago men to harvest it with a sickle, for which in return the Manjago get part of the harvest.

A disadvantage of sickle harvesting is that the harvest needs to be threshed immediately after harvest in the field because it is bulky. This is not necessary with panicle harvesting (harvesting with a small knife), since the amount of stalk is much smaller and the panicles are tightly packed in bundles, which makes it possible to thresh the rice if there is a need and spread labour for threshing over time. In flooded lowlands there is also no space in the field for threshing and panicle harvesting is more practical. Furthermore, threshing is a tough job and especially if the quantity is large, women prefer to spread the threshing over a longer period. Some women think that threshed rice does not store as well as unthreshed rice, because insects can enter the seeds more easily due to damage caused by threshing. Another advantage of panicle harvesting is that the rice can be tied into big bundles, which are easy to transport, particularly in swampy areas (Dey, 1982).

One other, important, reason for women to continue panicle harvesting is that it enables separation of off-types when harvesting seed (this will be discussed further in Chapter 7). Often, women have a small calabash or bucket in which they put all the off-types, among them *O. glaberrima* and diseased panicles (for further details, see Chapter 4). A few varieties are also sown deliberately mixed, and panicle harvesting enables the separation of the varieties, unlike sickle harvesting.

If harvesting is done by one or two women, the whole harvesting process can take some weeks. In the *tandako* the harvest often stays in the field till the end of the harvesting period. The women make a small bench in the field on which they can place the rice, to prevent it from being damaged by mice and termites. They use a shelter of palm leaves or plastic to protect it from the rain. In the transitional zone where conditions are comparable to the uplands this practice is not common. This confirms that in farmers' perception the transitional zone is part of the lowlands.

Jola women are sometimes assisted by male family members who use a sickle for harvesting. Whether the men really help varies per compound and per year. Harvesting shows the only difference observed between Mandinka and Jola farmers: From ploughing till bird-scaring, rice cultivation is exclusively done in the same way by Mandinka and Jola women, while during harvesting, men occasionally help in some Jola families, but not in Mandinka families. This is one of the few practices revealing that in the past Jola men and women cultivated rice together[6].

Storage

Differences in storage practices for rice seed and grain seem to be mostly related to the area farmers are living in and less to the ecological conditions (Table 3.4). In Kiang and Kombo almost everybody stores the grain unthreshed, while in Fuladu the majority of farmers store the grain threshed. For seed, almost all farmers in Kiang store it unthreshed, while in all other areas about 50% of the farmers store it threshed. However, there are also clear differences between villages in the same area, which indicates a factor I will term village culture is at work.

The reason that seed is stored unthreshed is that pounding (threshing) will damage the seed and pests can, consequently, affect the seed more easily. The reason to store seed threshed is that it can be put in a container or bag, to prevent pest infestation. The first reason is probably 'old' knowledge, whereas the second reason is 'new' knowledge. Most farmers store both grain and seed in the same way (Spearman rho correlation = 0.402, p = 0.000, N = 132), either unthreshed (47%) or threshed (21%).

Table 3.4: Storage methods used by farmers in percentages for rice grain and seed in different ecologies and districts (data from 2002-questionnaire).

	tandako	fs *faro*[1)]	fs+p *faro*	fp *faro*	fm *faro*	Kombo	Foni	Kiang	Fuladu
storage of grain									
threshed	22	45	12	44	5	13	48	5	70
unthreshed	78	55	85	52	95	86	52	95	20
both	0	0	4	4	0	2	0	0	5
storage of seed									
threshed	72	45	50	33	5	48	52	5	40
unthreshed	28	52	39	63	90	48	45	90	55
both	5	3	11	4	5	5	3	5	5

[1)] fs *faro* = farmers who broadcast rice; fs+p *faro* = farmers who broadcast and transplant rice; fp *faro* = farmers who transplant rice; fm *faro* = farmers who transplant rice in associated mangrove lowland

[6] If you tell Mandinka men that they help women less than Jola men, they say this is not true, since Mandinka men do the clearing (like Jola men), which is considered the toughest job of the rice cultivation, and in some cases they help bring the harvest home (like Jola men).

3.3 Millet

Ecology and land use

In most villages more fields are available for crops such as millet, sorghum, maize and groundnut than for rice. In Kombo many farmers complain about land shortages, but up-country (in the east) land is usually not a problem (see Chapter 2). Various systems of crop rotation and shifting cultivation are used for these crops. Often, millet and groundnut are rotated every season, but it also happens that a farmer grows millet in the same field for several years and then changes to groundnut, or leaves it uncultivated for some years. The advantage of rotating millet and groundnuts is that because groundnut is unsusceptible to striga, it reduces striga pressure in the next season when millet, which is susceptible to striga, is grown.
Three main types of millet can be distinguished, each grown in different ecological zones: two types of late millet and one type of early millet. In Western Division (WD) most farmers grow late millet with bristles, in Mandinka called '*sanyo*' (Figure 3.4). In the southern part of URD, Fuladu district, farmers grow another type of late millet without or with very short bristles, called '*majo*'. In the rest of the country, farmers grow early millet (also without bristles), called '*suno*'. Of the areas interviewed, *sanyo* is grown in Kombo and Foni, *majo* in Fuladu and *suno* in Kiang.

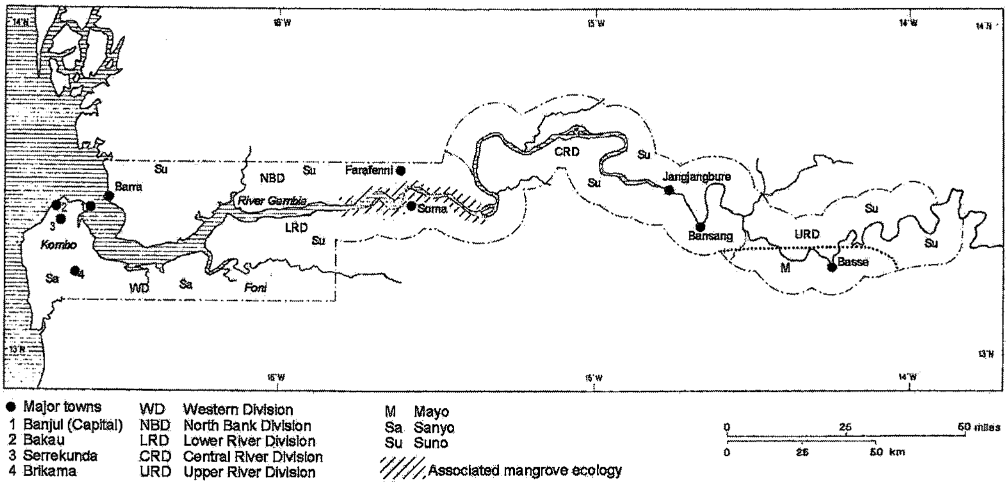

Figure 3.4: Ecological zones for the three main millet types grown in The Gambia.

Ploughing and sowing

The sowing periods for early and late millet differ. Early millet should be sown as early as possible, preferably before the rains start, so flowering has finished before the annual flight of the blister beetle begins. This beetle sucks seeds empty when in the milky stage. Late millet has a wider window for sowing. In Western Division most farmers prefer to sow it at the beginning of the rainy season when grasses are still short, which makes ploughing easier, but it might actually be better to sow it a few weeks later to avoid the blister beetle at the grain-filling stage. In that case late millet should be sown in a field with good soil fertility for it to catch up in growth. One farmer in Tujereng does sow his millet later, but for a different reason: He says too much rainfall is not good for millet. His father originally came from Southwest Casamance where rainfall is higher and distributed over a longer time period and millet cannot be sown early. In Fuladu it is a common practice to sow late millet later in fields with good soil fertility.

Furthermore, whereas early millet is photo-period insensitive, late millet is photo-period sensitive, which explains why the time of sowing is less important for late millet than for early millet.

In Tujereng fields are usually ploughed using oxen, and rarely by tractor. Only a few people have oxen, and the very few available tractors are owned by people in neighbouring villages. After making ridges with the plough, sowing is done by hand on top of these ridges. Demarcations where to drop seed are made by stepping in the soft soil, either by following the ridges, or by jumping from ridge to ridge. The distance between the ridges is usually 60 cm, and the distance between the plants in the rows depends on the preference of the farmer (60-90 cm). Fields sown with a row seeder are usually not ploughed. In such fields distances between rows are also about 60 cm, and distances between plants in the rows irregular (often less than 60 cm).

One reason why many farmers in Kombo make ridges is to prevent the millet from becoming waterlogged. This also explains why in Kombo more people sow by hand than in other areas (Table 3.5). Another advantage of ploughing compared to sowing directly (without ploughing) is that weeds and grasses are buried and the millet has a better start. The disadvantage is that one has to wait till the soil is moist enough for ploughing. The advantage of not ploughing but sowing directly is that the farmer is not dependent on plough owners and sowing can be done any time, although some extra weeding will be needed. If a farmer needs to hire oxen or a tractor for ploughing, he usually has to wait a long time before they come, and it is always possible that the appointment is shifted or cancelled. Early millet needs to be sown as early as possible and farmers prefer to sow it in dry soil for the seed to germinate immediately when rain comes. In that case sowing with a machine is preferable.

Table 3.5: Sowing method used for 3 millet types (*sanyo*, *suno* and *majo*) in different districts (data from 2002-questionnaire).

millet type district	*sanyo* Kombo	*sanyo* Foni	*majo* Fuladu	*suno* Kiang	total
N =	58	29	20	20	127
machine (%)	32	45	60	65	45
by hand (%)	62	48	35	20	48
both (%)	5	7	5	15	7

A few people, particularly Jola, plough their millet field by hand (these people plough all fields, including the groundnut field, by hand), which has several advantages. It allows independence from oxen and tractor owners. The weeds are covered completely; very few weeds survive and a very clean sowing bed is created which gives the crop a head start over the weeds, and weeding can be done later, less often and with less effort. Ploughing can be done when the soil is relatively dry, whereas when ploughing with oxen the soil needs to be moist. Tree stumps can easily be avoided.

The disadvantage of ploughing by hand is that it is very labour-intensive and time-consuming, because after the first turning of the soil a second layer of soil needs to be put on top of the first layer. Using oxen for adding the second layer decreases the workload a little.

Field size

Because it is difficult for farmers to explain field size in metric units, they were asked how much seed they used to sow their millet fields. Most farmers explained the quantity in bundles of millet, while others explained in containers, bags, barrels etc, of which the volume or weight was estimated. In Kombo (especially in Tujereng) estimations were more often done in volumes, whereas in the other districts, estimates were mostly made in bundles. Farmer volumetric estimates were then converted to a rough area estimate.

Although field size differs between villages, the differences are not significant (Table 3.6). Fields sown by machine tend to be larger than those by hand (2.6 ha compared to 2.2 ha for hand sown fields, but not significant). Other factors that help to explain variation in field size are the importance of millet to the farmers and the availability of land and labour. Along the coast many farmers grow cash crops like cassava, watermelon and fruit trees instead of millet. Because of the vicinity of the urban areas, young people prefer to find work in the city instead of farming (see Chapter 2). Particularly in Tujereng, field sizes tend to be smaller than in the other villages. In the past few years, farmers experienced bad harvests which they cannot explain (too much rain is sometimes suggested). Along the coast birds are a far bigger problem on grain crops than in other parts of the country.

Table 3.6: Average size (in ha) of millet fields for the various villages, from West to East (data from 2002-questionnaire).

village	millet type	district	respondents (N)	mean	std. deviation
Tujereng	*sanyo*	Kombo	7	0.8	0.64
Kartung	*sanyo*	Kombo	4	2.4	2.08
Kitti	*sanyo*	Kombo	17	2.0	1.38
Faraba	*sanyo*	Kombo	17	2.5	1.72
Janack	*sanyo*	Foni	9	2.6	1.61
Batabut	*sanyo*	Foni	10	2.3	1.21
Sangajor	*sanyo*	Foni	10	3.5	3.37
Jiroff	*suno*	Kiang	10	3.1	3.03
Massembe	*suno*	Kiang	9	2.3	1.51
Damphakunda	*majo*	Fuladu	9	3.6	1.58
Sanending	*majo*	Fuladu	10	1.5	0.70
total			112	2.4	1.93

Thinning and weeding

Millet seed is very small and during sowing 5 to 10 seeds are dropped together in one hill. Although millet germinates quite easily, germination varies from field to field and year to year, depending on the humidity of the soil and the presence of ants and birds. It is possible to send somebody to the field for bird scaring, but ants remain a problem.

Usually, and particularly if germination is good, the hills need to be thinned, so that 2 to 4 plants are left. In Kiang, the only interviewed area where early millet is cultivated, slightly more plants are left per hill than in the other areas (Table 3.7). Early millet flowers earlier, and probably tillers less than late millet, which means more plants can be left per hill.

When germination is good and transplanting is not necessary, farmers might opt to do the thinning together with the weeding. In most cases, however, some transplanting needs to be done to fill up the empty hills and thinning is done after weeding. If a farmer was short of seed to plant the entire area, he can also use the thinned plants to fill up the unplanted portion. If transplanting is done during rainy weather and in wet soil, most plants survive and quickly resume growth. It is also possible to separate the tillers of a millet plant and to transplant these. A few people do not even sow their field, but go to other farmers to ask whether they can help with the thinning. In return they get the uprooted material. Planting millet instead of sowing has several advantages:

- If planted in a well ploughed 'clean' field (all weeds well covered with soil), weeds cause only few problems and one might even not need to weed the field.
- There are no problems with poor germination after sowing and no need for re-sowing.
- If planted during good rains, it means immediate good establishment.

But the technique also has disadvantages compared to sowing:

- Uncertainty about the availability of planting material due to poor germination in other people's fields.
- Possible poor establishment, if transplanting is not followed by heavy rains.
- It might prove difficult, at the time of ploughing, to cover all weeds and create a clean field. It might also mean that extra clearing of the field is needed before ploughing.

Table 3.7: Number of plants left after thinning by farmers for 3 types of millet in different districts (data from 2002-questionnaire).

millet type district	*sanyo* Kombo	*sanyo* Foni	*majo* Fuladu	*suno* Kiang	total
respondents (N)	58	29	20	20	127
no thinning (%)	5				2
1-2 left (%)		10		5	3
2-3 left (%)	40	38	20	5	31
3-4 left (%)	40	31	55	50	42
4-5 left (%)	10	21	10	30	16
5 or more (%)	5		15	10	6

Table 3.8 shows the number of times farmers weed their field, in relation to the sowing method. Farmers who sow by machine weed their field more often than farmers who sow by hand (t-test, $p = 0.001$). As explained earlier, people who sow by hand often plough their field first, which gives a head start to the millet compared to the weeds. In Fuladu, however, there is no difference at all in the impact of way of sowing on weeding.

Most farmers weed their field twice. Weeding a third time would be better, because it is only later on in the season that striga germinates, but at that stage the millet plants have grown big and their leaves easily scratch and cut the skin. In Tujereng a few farmers did not weed at all because they prioritised their cash crops. Because millet grows much taller than weeds, there will always be some harvest.

Table 3.8: Average number of times farmers weed millet fields compared for different sowing methods in different districts for 3 millet types (data from 2002-questionnaire).

millet type district	*sanyo* Kombo	*sanyo* Foni	*majo* Fuladu	*suno* Kiang	total
respondents (N)	58	29	20	20	127
by machine	2.1	1.9	2.1	2.0	2.0
by hand	1.7	1.4	2.3	1.5	1.7
both	1.7	2.0	3.0	1.7	1.9

Soil fertility

As part of this research soil analysis was also conducted on millet fields in the four villages Tujereng, Faraba, Kitti and Janack to know whether there are any differences in soil characteristics between the millet fields of these four villages, and to understand whether these differences might influence farmer variety choices or exert a divergent selection pressure (see Chapters 4 and 10). The analysis shows that in all villages millet is grown in sandy-loam soils and that soil texture does not vary much between villages (Table 3.9). The pH in Janack is significantly higher than in the other villages. The differences in phosphorus are caused by the inclusion in the samples of a few fields with high phosphorous levels situated near compounds. The fields further away all have low phosphorous levels. In general, soil fertility is low.

Table 3.9: Soil analysis data of millet fields in 4 villages in Western Division (samples were taken in the fields of farmers interviewed in 2000).

village	# fields	sand %	clay %	silt %	pH water	avl. P (ppm)	N (%)	org. mat. %	EC[1] mmhos/cm
Tujereng	8	57	17	26	4.9	6.1	6.0	1.0	0.043
Kitti	4	70	18	12	4.8	2.8	6.0	1.1	0.040
Faraba	4	65	15	20	5.0	2.1	7.0	1.4	0.043
Janack	5	66	14	20	5.7	4.7	5.6	1.0	0.048
total	21	63	16	21	5.1	4.4	6.1	1.1	0.043

[1] Electrical Conductivity

Pests and diseases

Blister beetle is the most important pest in millet, particularly in early millet, and sucks millet seeds empty at the milky stage. The period blister beetles suck millet seeds is from mid-September to mid-October, when the rains stop. If early millet is sown before the first rains, it will mature before or during the first appearance of the blister beetles and damage will be small. If early millet is sown later, all seeds can be sucked empty by the blister beetle, resulting in a complete crop failure. Whereas early millet is photo-period insensitive, late millet is photo-period sensitive and it starts flowering mid-October, just after the blister beetles have disappeared. Hence, blister beetles usually do not cause much damage in late millet. However, if the rains continue up to the end of October, blister beetles can cause serious damage in late millet. According to Darboe (personal communication) blister beetle infestation varies from year to year. It might also be possible that the time of the year that the beetle feeds on millet differs slightly by region within The Gambia, but no research has been conducted to provide detailed information.

Other pests that can cause damage include stem borers and striga. By rotating millet with groundnuts, farmers can reduce striga in their millet fields. Diseases are not a mayor problem during the vegetative stage of millet growth but become potentially more important during the period from flowering to maturity, if it rains frequently during that period. When late millet starts flowering, the rains are becoming less frequent.

Inputs

Both chemical fertiliser and cow dung are often used (mostly at an irregular basis) to fertilise the fields, but the percentages of farmers who use either differ by area (Table 3.10). In Fuladu and Kiang almost all farmers use chemical fertiliser, while in Kombo and Foni about 50% of the farmers do not. In Kiang more farmers use cow dung than in the other areas. This means that 32% of the farmers in Foni and 39% of the farmers in Kombo do not apply any fertiliser at all on their millet fields. Farmers in Tujereng say *sanyo* does not need fertiliser to grow well, which might explain the lower fertiliser rates in both Kombo and Foni. Some farmers say that early millet needs good soil fertility to be able to yield well, which explains the higher fertiliser use in Kiang. A requirement to successfully sow *majo* in Fuladu at a later stage is good soil fertility, which might explain the higher fertiliser use in this district.

Particularly in Kiang many farmers (50%) use insecticides. *Suno*, grown in Kiang, is more easily affected by blister beetles than *sanyo* and *majo*, which explains the high insecticide use. The percentage of farmers who use herbicide is very low in all districts. In general, weeds are not considered a big problem in millet. Spearman rho correlations (significant at 0.000 level) between the use of chemical insecticides and the use of chemical fertiliser, cow dung and chemical herbicides indicate that farmers who use insecticides also tend to use other inputs. People for whom millet is an important crop tend to use fertiliser, cow dung, and insecticides more often.

Table 3.10: Percentages of farmers who use inputs on various millet types in different districts (data from 2002-questionnaire).

input	millet type district	*sanyo* Kombo	*sanyo* Foni	*majo* Fuladu	*suno* Kiang	total
	respondents (N)	62	29	20	20	131
chem. fertiliser	every year	12	4	55	15	18
	irregular	33	43	35	70	42
	never	54	54	10	15	41
cow dung	every year	7	21	15	30	15
	irregular	40	21	35	50	37
	never	53	59	50	20	48

Harvesting

Harvesting is done by knocking down the plants, leaving the spikes to dry for a couple of days, followed by cutting off and piling the spikes on heaps. In most parts of Western Division (including Tujereng) *sanyo* is grown, which has bristles on the spike. These bristles need to be removed before tying the spikes in bundles and transporting them to the compound. It seems every farmer does this job his own way, and probably it also depends on the circumstances of the moment. In 2000, when the harvesting coincided with Ramadan, many farmers delayed part of the harvesting process until after the end of fasting.

In Kiang and Fuladu millet does not have bristles, and the harvesting process is much easier: After the drying of the spikes, these can be made into bundles and taken home. Among the Jola and Fula, women sometimes help with the harvesting of the millet, although not often.

Preferably, threshing of *sanyo* is done in the field. Because bristles and other parts of the flowers, which itch a lot, are released into the air during winnowing, threshing in the field has the advantage that the compound remains clean. If the millet harvest is very large, however, the millet needs to be threshed in batches in the compound. Millet without bristles does not itch much and can be threshed more easily in the compound.

Storage

For millet, there are clear differences in storage methods between millet types and areas. *Suno* seed and grain is stored unthreshed, *sanyo* grain and seed is often stored threshed, whereas for *majo,* grain is stored threshed and seed is stored unthreshed (Table 3.11). So, except for *majo*, most farmers store grain and seed in the same way (Spearman rho correlation = 0.461, p =

0.000, N = 104). In Kombo more farmers store their seed threshed than in any of the other areas, including Foni, where farmers also grow *sanyo*.

The reason that most farmers keep their seed unthreshed is that, according to farmers, the threshing can damage the seeds what makes it easier for insects to enter. However, because of the spaces in between the spikes, eggs laid by insects can easily hatch and when mature in turn lay their eggs in the seed. Luckily, millet seed is not affected severely by storage pests. Only 39% of the farmers store their seed threshed. Storage in a good container is the best way of storing seed, since insects cannot readily damage it. If the seed is stored outside, the spikes are put in a bag and hung on a pole in the compound. This method is not common.

Only a few farmers store their millet grain outside for the whole dry season. Many farmers store their millet outside for some time, until the women have time to thresh it. If it is stored outside, it is either stored in a fenced area or on top of a platform also used to store groundnut stover.

Table 3.11: Frequency of storage methods used for grain and seed for three millet types in different districts (data from 2002-questionnaire).

millet type district	*sanyo* Kombo	*sanyo* Foni	*majo* Fuladu	*suno* Kiang	total
respondents (N)	62	29	20	20	131
storage of grain					
inside, threshed	79	62	80	20	66
inside, unthreshed	19	34	20	80	33
outside, threshed	0	0	0	0	0
outside, unthreshed	2	3	0	0	2
storage of seed					
inside, threshed	62	41	0	10	39
inside, unthreshed	31	55	95	90	56
outside, threshed	2	0	0	0	1
outside, unthreshed	5	3	5	0	4

3.4 Discussion

Since millet is grown by men and rice by women, the question may arise whether differences in cultural practices are related to gender. However, differences in crop phenology and ecological conditions can explain many differences between rice and millet in terms of husbandry practices, like ploughing, sowing, plant distances, weeding and harvesting. Plant distances are clearly related to plant phenology. Another example is weeding. Millet is weeded in a rough way, compared to the careful weeding of rice done by women. The growth habit of millet allows transplanting. Normally, transplanting is done after the weeding so it does not matter if many millet plants are cut during weeding. Men also weed groundnuts very carefully and hardly cut any plants because it is not possible to transplant groundnuts. Some differences are related to a particular ecology. One example is the use of insecticides. In general, more men use insecticides in millet than women do in rice. This difference is related to *suno* which, if not sown in time, is easily affected by blister beetles.

But not all differences in cultivation can be explained by crop phenology and ecological conditions. Although one might expect a similar use of fertiliser for both crops at compound level, there is no correlation between men and women at the compound level using fertiliser. Since rice and millet are both subsistence crops, gender is the most logical factor to explain this separateness. This indicates that rice and millet are two separate farming systems, even though cultivated by wives and husbands from the same compound. Ploughing and sowing are two other practices indicating that millet and rice are two separate farming systems. In the drier areas of the lowlands it would actually be possible to use oxen or tractors for ploughing or donkey for row seeding, but both women and men are very reluctant to put such ideas in practice. According to an extension officer, men do not want to share their resources with women, even though in the long run it will benefit the men. Another explanation is that women want to remain independent because if they would show they are very capable in handling machinery, they might end up working the men's upland fields as well (Baker, 1995). The fact that roughly 150 years ago women were pushed into rice cultivation by the men when groundnut proved a profitable cash crop (Watts, 1993) might well substantiate the latter explanation. Before 1850, men also ploughed the rice fields, but with the increased cultivation of groundnuts, after 1850, men did not plough the rice fields anymore (Watts, 1993). Nowadays, men still continue clearing of upland rice fields, because clearing is a laborious and tough job which women would not be able to do. But another factor to consider is that if women were to do the clearing of the land, they might claim land rights, particularly if they had been the first to clear the land (see Chapter 2).

Interestingly, there is one aspect that does show a clear correlation between rice and millet farming - seed storage. In most cases, within the same compound both rice and millet seed is either stored threshed or unthreshed (Spearman rho correlation = 0.354, p =0.000, N= 124). Because it is women who thresh seed, it is indirectly their decision whether rice and millet seed is stored threshed or unthreshed. For grain, this correlation is less strong (Spearman rho correlation = 0.181, p = 0.041, N = 126), which might be explained by differences in consumption patterns and labour availability. Whereas for rice, differences in storage methods to some extent are related to ethnicity to some extent, for millet, there is no such relationship.

The quality of seed stored by farmers was not examined in this study. The effects of seed quality on yield were also beyond the scope of this study. For both rice (Osborn, 1990) and millet (Ndjeunga, 2002), the storage methods of West African farmers generally affect seed quality to some degree, but seed germination is generally good. The easiest way to improve seed quality and one which has probably the biggest effect is to dry seed very well and to store it threshed in closed containers. In the western part of the country, which is closer to the urban areas where containers are readily available, this practice is already more common than in the eastern part of the country. Storing seed unthreshed, as is typical in the eastern part of the country, was probably the best way to store seed before the wide availability of closable containers.

Except for the storage methods of seed, there are no differences in practices that can be readily related to economic or socio-cultural factors. The differences between farmers in the use of inputs can be found in all villages. For millet, ploughing tends to be done more often in the western part of the country, where rainfall is slightly higher. This also means that in the western part of the country planting distances tend to be wider because the plough determines the distance between rows.

The use of millet seedlings indicates that farmers think that there are few or no differences between seed lots of millet. This will be discussed further in Chapter 4.

The main constraint mentioned by both men and women is lack of fertiliser. For both rice and millet, about 40-50 % of the farmers use chemical fertiliser irregularly. Some people complained that because of land scarcity soil fertility has deteriorated (This claim is in contradiction with Figure 2.9). It seems likely that decreased soil fertility is related to unequal land access. As was also mentioned in Chapter 2, labour is another constraint for both crops.

For upland rice, women perceive clearing, weeding and bird scaring (particularly in Tujereng) as major constraints. For millet, particularly for early millet, blister beetle is a serious pest. For both crops, cattle can also cause problems. Other pests and diseases were not often mentioned. Threshing, done by women for both crops, was mentioned as a constraint by women.

3.5 Conclusions

The information in this chapter shows that farmers' practices are shaped by ecological and socio-economic conditions. Given the conditions and constraints, farmers look for the best farming practices. Social interaction and village discourse also influence farmers' practices, but do not necessarily lead to wide uptake of the most suitable or ideal practices. More information is needed to indicate to what extent farmers' practices are shaped by ecological and socio-economic conditions and to what extent by village discourse. Secondly, for both crops, farming practices differ between farmers, even within a village or within the same ecology. Farmer practices also vary between years, influenced by ecological and socio-economic factors, such as rainfall and labour availability.

4 Selection pressures within varieties

4.1 Introduction

In Chapter 1 it was explained that selection pressure, next to seed flow and pollen flow, is one of the main factors in farmer management of gene flow. In this chapter selection within varieties (including agro-ecological selection pressures) and divergence of seed lots of the same variety are discussed. Chapter 5 will discuss selection between varieties. That new genetic diversity develops through farmer selection is suggested in literature. Busso *et al.* (2000) found that seed lots of the same millet variety can diverge due to farmer selection, farming practices and agro-ecological conditions. This is facilitated by the genetic diversity within farmer varieties of millet and by the outbreeding nature of millet.

Tin *et al.* (2001) suggest that rice varieties also change in relatively short periods of time (less than 10 years) due to farmer selection. For rice, it is also suggested that farmer selection is both effective and essential to maintain the characteristics of each distinct cultivar over time, since 'rice interbreeds readily' (Lambert, 1985) and 'cross-pollination occurs in varying degrees' (Bray, 1986). However, estimates of the rate of cross-pollination in rice are low, ranging between 0% and 1% (Grist, 1986; Purseglove, 1985). Since the levels of genetic diversity within rice varieties are limited it seems unlikely that rice varieties will in fact change much genetically over short time periods. How much change might be expected, and why, is a subject of this chapter.

Understanding the effect of farmer seed selection

To better understand the effect of farmer seed selection it is essential to know the efficiency of farmer selection. Unfortunately, the efficiency of farmer selection has not been studied much. According to Berg (1993), farmer selection is less efficient than breeder selection. Soleri *et al.* (1999) found that farmer selection can be as efficient as breeder selection. However, despite this finding, farmer selection within maize populations over 2 years resulted in very few significant differences (Soleri *et al.*, 2000). In another (3-year) study on maize, farmers who used 'breeders' selection methods did achieve significant yield increases (Smith, 2001). Breeder selection in that study meant that farmers used stratified selection and not only looked at the traits of the cob, but also at the number of cobs per plant in the field. So, whereas Soleri *et al.* (2000) suggested little or no yield increases are possible, Smith *et al.* (2001) indicated that farmers using breeder selection could achieve significant yield increases. According to Soleri *et al.* (2000) the main reason the selection experiment over 2 years did not show much effect was the huge environmental variation in farmers' fields.

Another reason why the study of Soleri *et al.* (2000) did not show any effect might be that genetic improvement as the result of selection is a very erratic process and 2 years is too short a period to show any patterns. The selection experiment to increase and reduce oil and protein content in maize under controlled field conditions conducted by the University of Illinois (Dudley *et al.*, 1974) also showed irregular patterns. The effects on oil content are shown in Figure 4.1. Some years show clear improvements, other years show hardly any improvement, while yet other years show negative effects. A selection experiment with oats under controlled field conditions showed a slight decrease in yield in 1969 and a clear increase in 1970 (Frey, 1990). The probable explanations for these irregular patterns in selection response are G × E interactions and the continuous recombination among linked genes (Frey, 1990; Barton and Turelli, 1989; Hill *et al.*, 1998). Another factor might have been change in selection criteria as a cause of yield increase in the case study of Smith *et al.* (2001). After years of selecting only for cob traits within the same population, no advance was possible anymore, whereas with the selection for traits like cob number per plant, a yield increase was still possible. This, however, seems to be in contradiction with the results of the selection experiment to increase oil and protein content in maize. Much remains to be clarified about the effects of farmer selection.

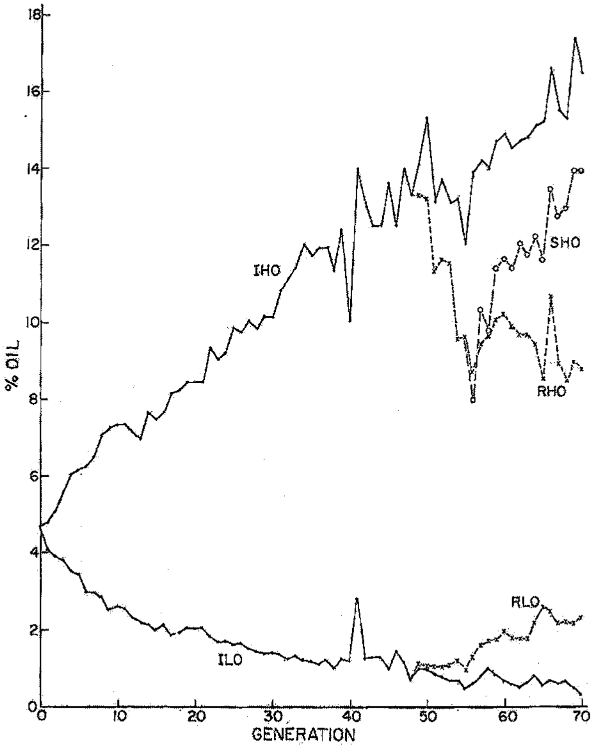

Figure 4.1: The effect of various selection regimes on oil content in maize; IHO = Illinois High Oil (selection for high oil content), ILO = Illinois Low Oil (selection for low oil content), RHO = Reverse High Oil (selection for low oil content), RLO = Reverse Low Oil (selection for high oil content) and SHO = Switchback High Oil (selection for high oil in RHO), from Dudley *et al.* (1974).

Agro-ecological selection pressures

Apart from farmer selection, agronomic and ecological factors also exert selection pressures on plant populations. Allard (1988) showed for barley (and also other crops) that, if the progeny of many crosses between different varieties are sown and harvested without selection for several generations (up to 70 generations), during the first 4-5 generations a dramatic yield increase of up to 30% per generation is visible, after which the increase per generation slows down to about 2-3%. What kind of increase might be apparent after a further 70 generations is not known. African rice and pearl millet were domesticated 3000 to 4000 years ago. If the situation was in any way comparable to the data reported by Allard (1988), then we presume production increases in the early generations of domestication. But we might also expect that over 3-4000 years annual increased slowed down or diminished to non-measurable levels. Even if nowadays yields might still increase with an annual 2%, such small differences would be hard to detect in experiments covering only 2 or 3 generations because it would require ideal, uniform trial conditions to be able to differentiate between 1000 kg/ha and 1041 kg/ha.

The barley experiment also showed that natural selection and human selection are not necessarily counter-effective (Allard, 1988). Under natural selection, those plants that can produce the highest number of seeds are the most successful and this is also what farmers look for. Other traits that farmers select for are larger heads, larger seeds, easier threshing, seed colour, flavour, texture and storage quality (Harlan, 1975). Because many of these traits influence each other, it is difficult to disentangle the effects of natural and human selection.

As explained above, a 2-year experimental period seems too short to estimate the efficiency of farmer seed selection. Thus, although little information is available on efficiency, the main question treated in this chapter is whether farmer seed selection can have any impact on the genetic background of rice and millet varieties leading to genetic divergence between seed lots of the same variety. A second question is whether seed lots of the same variety collected in different villages actually showed such differences, and whether this is more common for millet than for rice. Theoretically this is more feasible for millet than for rice, since millet is an outbreeding crop and thus genetically more diverse than rice (an inbreeding crop). In this chapter, farmer seed selection methods of rice and millet will first be described based on information from questionnaires and interviews, after which differences between seed lots of several rice and millet varieties will be described and analysed based on field trials.

Apart from seed selection practices and agro-ecological factors, there is little reported information about the role of socio-economic factors in shaping crop populations. In this chapter a range of candidate factors (see Chapter 3) and possible interactions between these factors will be discussed.

4.2 Materials and methods

The data presented in this chapter are derived from interviews and field trials.

Interviews

The quantitative data on seed selection were collected by means of a questionnaire in 2002 (Appendix 2) and the qualitative data were collected via informal and semi-structured interviews between 2000 and 2003. Information acquired through informal discussions with NARI researchers is also included.

The categories used to analyse the data on rice and millet are the same as used in Chapter 3. For rice, these categories were:

- women who broadcast rice in *tandako* (typical uplands),
- women who broadcast rice in *faro* (transitional zone of the lowlands),
- women who transplant rice in *faro* (flooded lowland),
- women who broadcast and transplant rice in *faro* (in different fields in the transitional zone and flooded lowland, respectively),
- women who grow rice in mangrove-associated *faro* (lowland where rice is transplanted after the salt has been washed from the soil).

For millet these categories were:

- *sanyo* (late millet, with bristles, grown in south-western part of The Gambia; see Figure 3.4)
- *majo* (late millet, without bristles, grown in south-eastern tip of The Gambia)
- *suno* (early millet, without bristles, grown in the rest of the country)

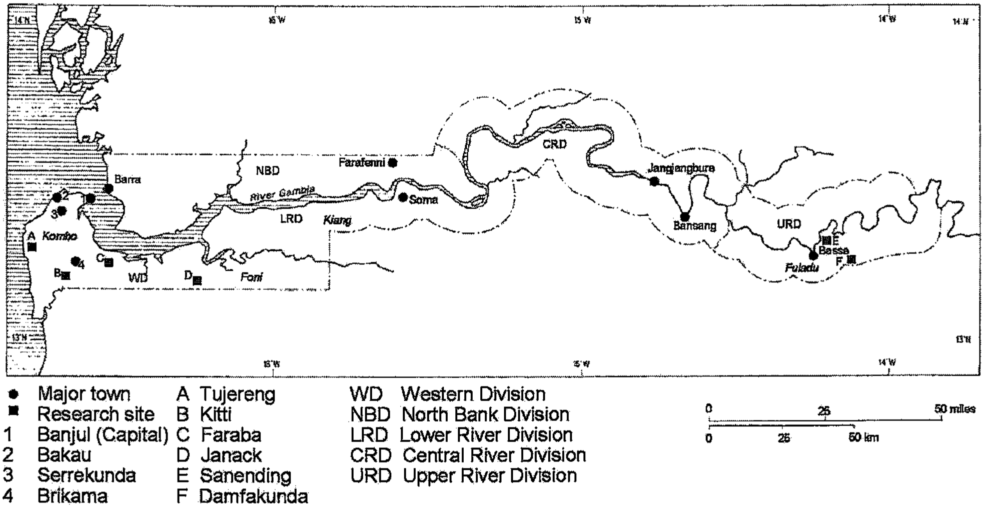

Figure 4.2: Locations of the villages of which seed samples were used for an analysis on variation within varieties.

Field trials

Study material

The rice and millet samples used for analysis belong to a larger set of collected samples. For analyses of intra-varietal variation, rice and millet seed lots were collected in various villages (Figure 4.2). Rice and millet genetic diversity at village level will be discussed in Chapter 10. Per rice sample, half a kilo (about 300 panicles) was taken at random from the harvest as a representative sample of a variety. Based on farmers' descriptions of the morphological identity of varieties, all off-types (both contaminations and products of cross-pollination) were carefully removed from each rice sample. These samples were used for the trial in 2001. For the trial in 2002, the harvest of the 2001 trial was used. For millet, farmers could not indicate clearly which spikes belonged to their varieties and which were off-types. Hence, the millet samples obtained from farmers could not be cleaned. To obtain representative samples of millet varieties, in 2000, per farmer seed lot 20 seeds of each of 100 spikes were bulked. This seed was meant for the trials in 2001 and 2002, but germination tests before the rainy season in 2002 indicated that the seed was not viable anymore. It was possible to obtain new seed samples for the trial in 2002 from most of the farmers from whom I collected seed in 2000, although most of these samples consisted of threshed seed. When asking for these samples from farmers, I confirmed they had not lost or replaced their seed.

For the analyses in this chapter, only varieties for which multiple samples were obtained are used. The analysed samples were obtained from the villages of Tujereng, Kitti, Faraba and Janack. For rice, samples of 8 varieties were compared and, for millet, samples of 4 varieties were compared.

Trial lay-out

Both rice and millet trials were conducted in farmers' fields in Tujereng under researcher management in 2001 and 2002. For each of the rice trials, a forest area was slashed and burned. Compound fertiliser (NPK) was applied at a rate of 25:25:25 kg/ha, followed by ploughing of the site. Only a single fertiliser treatment was performed in order to follow the farmers' practices as much as possible and to prevent excessive lodging of farmer varieties. The trials consisted of 4 replications in which each plot consisted of 2 rows of 3 m spaced 30 cm apart. The distance between plants within rows was approximately 10 cm. Different samples with the same panicle morphology were randomised and sown adjacently in groups within each replication in order to establish whether they belonged to the same variety. These groups were randomised within each replication. In most cases, the samples within groups represented the same variety.

The millet trials were located in fields which had been left fallow for five years. Prior to ploughing, compound fertiliser (NPK) was applied. In 2001, fertiliser was applied at a rate of 25:25:25 but growth appeared poor, and in 2002, fertiliser was applied at a rate of 40:40:40 kg/ha to ensure good soil fertility. The trials were sown in a completely randomised block design with 4 blocks, with plots of 6 by 3.5 m, each consisting of 5 ridges. The distance between ridges was 70 cm and between plants about 80 cm.

Measured traits

Among the measured traits for rice, the following quantitative traits were used for analysis: seed length, seed width, ligule length, leaf length, leaf width, plant height and panicle length. For millet, the following quantitative traits were used for analysis: plant height, spike length, spike width, leaf length, leaf width, stem width, separation and days to 50% flowering. Morphological traits of rice and millet were measured following the guidelines of IRRI (1996) and IBPR/ICRISAT (1993), respectively (Tables 10.2 and 10.3).

Because of soil variation in the rice trials, for each variety, one replication was excluded from measurement. For rice, each year 18 plants were measured across 3 replications, giving a total of 36 plants over 2 years. In 2001, the stand of one replication in the millet trial was very poor and excluded from measurement. Hence, for millet, 18 plants were measured across 3 replications in 2001 and 24 plants across 4 replications in 2002.

Data analysis

For the comparison of seed samples within varieties, univariate ANOVA in SPSS was used for the data of 2001, 2002 and both years combined. Of the varieties with several seed samples, the samples were sown randomised next to each other, within each replication, yielding a randomised block design for each variety with multiple samples. For both rice and millet, seed sample was considered as a stochastic variable in the analyses comparing samples of the same variety. Replication was also used as a stochastic variable in these analyses.

Values of wide-sense heritability were estimated in Excel, using the MS values obtained through ANOVA in SPSS. For rice, 40 varieties were used. Replication was not used as a variable. For millet, only those seed lots of the variety '*white sanyo*' which were included in the trial in both years (6 in total) were used. For millet, replication was used as a stochastic variable in these analyses. For millet, also the data of the 4-locations trial (see Chapter 11) were used to estimate heritabilities.

ANOVA for the various trials to estimate heritabilities were as follows:

Rice over 1 year with J replications:

	df	SS	MS	E(MS)
genotypes	I-1	SS_g	MS_g	$\sigma_r^2 + J\sigma_g^2$
residual	I(J-1)	SS_r	MS_r	σ_r^2

Millet over 1 year with J blocks:

	df	SS	MS	E(MS)
blocks	J-1	SS_b	MS_b	$\sigma_r^2 + I\sigma_b^2$
genotypes	I-1	SS_g	MS_g	$\sigma_r^2 + J\sigma_g^2$
residual	(I-1)(J-1)	SS_r	MS_r	σ_r^2

Rice and millet over K years and J replications / blocks:

	df	SS	MS	E(MS)
year	K-1	SS_y	MS_y	$\sigma_r^2 + J\sigma_{y\times g}^2 + IJ\sigma_y^2$
genotypes	I-1	SS_g	MS_g	$\sigma_r^2 + J\sigma_{y\times g}^2 + KJ\sigma_g^2$
year × genotypes	(K-1)(I-1)	SS_{y*g}	MS_{y*g}	$\sigma_r^2 + J\sigma_{y\times g}^2$
residual	KI(J-1)	SS_r	MS_r	σ_r^2

Millet over N locations and J blocks:

	df	SS	MS	E(MS)
location	N-1	SS_l	MS_l	$\sigma_r^2 + J\sigma_{l\times g}^2 + IJ\sigma_l^2$
genotypes	I-1	SS_g	MS_g	$\sigma_r^2 + J\sigma_{l\times g}^2 + NJ\sigma_g^2$
location × genotypes	(N-1)(I-1)	SS_{l*g}	MS_{l*g}	$\sigma_r^2 + J\sigma_{l\times g}^2$
residual	NI(J-1)	SS_r	MS_r	σ_r^2

For estimation of wide-sense heritability over one year the following formula is used (see Bos, 1990; Bos and Caligari, 1995; Hill *et al.*, 1998):

$\sigma_g^2 / (\sigma_g^2 + \sigma_r^2/J)$

For calculations of wide-sense heritability over two years the following formula is used:

$h_w^2 = \sigma_g^2 / (\sigma_g^2 + \sigma_{g*y}^2/K + \sigma_r^2/JK)$

For estimations of wide-sense heritability over one year and 4 locations the following formula is used:

$h_w^2 = \sigma_g^2 / (\sigma_g^2 + \sigma_{g*l}^2/N + \sigma_r^2/JN)$

In these formula g stands for seed lot; r for residual effect; y for year; l for location; J for number of replications or blocks; K for number of years; and N for number of locations.

Correlations between quantitative, morphological traits were calculated with the Spearman correlation test of SPSS using individual plant data of the trials conducted in 2002.

4.3 Results

Farmer seed selection

Rice

Time of separating seed

Most women separate their seed during harvesting, some after harvesting, and a minority after threshing or before sowing (Table 4.1). None of the women who grow rice in the lowlands only (Table 4.1: '*faro*, planted' and '*faro*, mangrove') separated their seed after threshing or before sowing. Those women who set aside seed during harvest usually harvest a good part of the field separately as seed, regardless whether this good part is in the border of the field or not. The 'good part' is often described as the part containing 'tall, healthy plants with big panicles and many seeds'. According to women the good part usually has a better soil fertility. However, in 2000, it was clear that upland rice growing near termite hills (termite hills have a clayey texture) was performing best, while in 2002, when rainfall was very erratic, rice growing near termite hills often performed worst because of drought stress. This means that the characteristics of the soil in which 'the good part' is growing can vary from year to year.

Only a small percentage of women separates seed after threshing or just before sowing (Table 4.1). These women broadcast their rice partially or completely, in *tandako* or in *faro*. Those women, who set aside seed just before sowing, store both seed and grain unthreshed, which allows some selection. Time of separating seed and selection are not necessarily one and the same event.

Table 4.1: Percentages of women who separate rice seed from the main harvest at various stages, for different ecologies (data from 2002-questionnaire).

time of separation of seed	*tandako*[1)]	*faro*, sown	*faro*, sown and planted	*faro*, planted	*faro*, mangrove	total
respondents (N)	18	38	26	27	20	129
during harvesting	50	58	46	48	70	53
after harvesting	39	24	42	52	30	38
after threshing	6	10	8	0	0	5
before sowing	6	8	4	0	0	4

[1)] *tandako* = farmers who broadcast rice in the uplands; *faro*, sown = farmers who broadcast rice in the transitional zone; *faro*, sown and planted = farmers who broadcast and transplant rice; *faro*, planted = farmers who transplant rice; *faro*, mangrove = farmers who transplant rice in associated mangrove lowland

Seed selection

Seed selection after harvest means that nice looking bundles of panicles are chosen and that the most eye-catching mix-ins and off-types are removed from these bundles. A woman turns a bundle to various angles with the one hand and picks out the off-types with the other hand. Because the panicles are tightly packed in such a bundle off-types are easily overlooked. It was mentioned that only bundles with good healthy seeds will be chosen for seed. In many cases, however, differences between bundles are very small or none whatsoever, which means that basically any bundle can be chosen for seed. In continuously flooded fields women do the selection after the harvest because it is possible the seed will get infected in the wet field when harvested, before being taken home.

It often happens at sowing time that a woman who selected seed during or after harvest and stored it unthreshed will perform a second selection just before threshing to remove off-types. How many cycles of selection a woman will perform is mostly determined by time available. Another important factor is patience: some women are able to do many selection rounds because they are never satisfied with the purity. Some women say they only do purification just before sowing, because after harvesting they immediately need to start their vegetable gardens. Some women even claim not to do any purification at all. The proportion of off-types can also differ from year to year due to the sowing of borrowed seed, the method of harvesting (careful harvesting by the owner of a plot or harvesting by a *kafo*) and accidents during storage or sowing. Selection is more or less necessary, depending on these contingencies.

Usually a woman practices the same kind of selection every year: 'you get used to a particular way of selection'. It sometimes happens however that women use different seed selection practices in different years, according to time constraints. Women who normally do seed selection during harvesting but, because of time constraints, need to call a *kafo* for help may be forced to select seed after harvesting. It is common that different varieties get mixed if a *kafo* is called for harvesting and the owner of the field is not present during harvesting. The following examples show that actual behaviour may differ from what women claimed during the interviews.

> One woman said that she does the selection during harvest; selecting big, heavy panicles. However, during harvesting she was ill, her field was mostly harvested by other women, and she said that for next year she will just put some seed aside as seed.
>
> Another woman explained that she harvests the seed from the more fertile parts of the field, but when confirming this in the field, she said that this year she did not apply any selection. This season she was very busy with other activities, and neglected her rice-field a bit (weeding only half of it), which also affected seed selection.
>
> A third woman said that she only removed off-types from the seed after harvesting. In one plot of her field, however, she harvested a part with small plants and small panicles separately and threshed them immediately, for consumption, leaving the better part of the field (from which seed would be reserved) for later harvesting.

Selection criteria

Asked about selection criteria, 83% of the women use such criteria, while 17% do not apply any selection at all (Table 4.2). The latter mostly set aside their seed after harvesting or separate the seed after threshing. As selection criteria, farmers most often mention that the panicles should be heavy (big), with big grains. Other criteria are filled seed, absence of diseases, and no mix-ins (other varieties). Women mentioned the latter more often during informal interviews, so it is possible that the percentages in Table 4.2 should actually be higher for 'no mix-ins'. All these criteria, except long grains (related to cooking quality), are clearly related to seed quality.

Also, if one considers that the average woman needs ± 40 kg rice seed, and the average panicle bears 2 g of seed, a woman needs to harvest 20,000 panicles to obtain 40 kg of seed. Harvesting 20,000 panicles and at the same time selecting the best panicles, is simply too laborious a job. So, selection is not about improving a variety genetically, but ensuring good physiological quality and reducing off-types.

Table 4.2: Percentages of farmers who select rice seed and their selection criteria, per ecology; total N = 129 (data from 2002-questionnaire).

	tandako	*faro*, sown	*faro*, sown and planted	*faro*, planted	*faro*, mangrove	total
farmers who do not select	33	11	15	15	20	17
farmers who select	61	89	81	85	80	81
no answer	6	0	4	0	0	2
selection criteria of farmers who select (N)	11	34	21	23	16	105
heavy panicle	82	62	63	57	38	58
big grain	46	47	44	52	24	43
filled seed	18	12	31	17	24	19
no disease	0	15	19	26	24	18
no mix-ins	9	18	31	13	10	16
many grains	27	6	6	9	0	8
long grains	9	0	6	0	0	2

There are small differences in selection criteria between areas and ethnicities, but these are mostly related to differences in ecologies. For women who grow *tandako,* panicle size is important, while many women who transplant rice mentioned that the seed should be disease free. This can be explained by the fact that, at harvesting time, fields are often waterlogged and the rice more prone to diseases. Furthermore, for women growing rice in two ecologies (transitional zone and flooded lowland), mix-ins is a more important criterion than for women who grow rice in one ecology. The harvests from different ecologies often end up in the same store, and depending on the available space, seed gets mixed easily. Furthermore, farmers who grow rice in two ecologies also grow more varieties (see Chapter 5), increasing the chances of seed becoming mixed.

Millet

Time of selection

For millet, separating seed during harvesting is also the most common method, but there are clear differences between the different millet types. For *suno* and *majo*, grown in Kiang and Fuladu, most farmers separate seed during harvesting (cutting of the spikes), while for sanyo, grown in Kombo and Foni, most farmers select the seed after harvesting (Table 4.3), particularly in Foni. Unlike *suno* and *majo*, *sanyo* has bristles which make selection during harvesting more difficult, because the desiccated flowers stick to the bristles, making it impossible to assess the quality of the spike. Instead, farmers often select seed during or after removal of the bristles, which is done some time after harvesting, when all millet spikes are collected in heaps. Some farmers who said they did not select during harvesting because of the bristles covering the spike added that there are other varieties with only few bristles in which selection is possible during harvesting. So, the presence or absence of bristles determines the selection method in millet.

Of those farmers who do the selection during harvesting, the majority looks for the best part of the field and for them it is the same whether that part includes the border or not. This means that, theoretically, farmers who grow *suno* or *majo* have better conditions under which selection might improve their seed genetically than farmers growing *sanyo*. However, farmers growing *suno* or *majo* only consider the quality of the spike during selection and not the vegetative parts. Including the vegetative parts in the selection process would practically be impossible because all plants are pulled down before harvesting (sometimes plants are more than 3 metres high), forming a jumble of stems and leaves. So, in the case of *suno* and *majo*, theoretically, selection during harvesting would be more effective than selection after harvesting, but because in both cases all plants are pulled down before the actual harvest, in practice, selection during or after harvesting will hardly make a difference.

Table 4.3: Percentages of farmers who separate millet seed from the main harvest at various stages, for 3 millet types and 4 districts (data from 2002-questionnaire).

time of selection	*sanyo* Kombo	*sanyo* Foni	*majo* Fuladu	*suno* Kiang	total
respondents (N)	56	29	20	20	125
during harvesting	32	24	85	65	44
after harvesting	47	69	0	5	38
after threshing	12	0	10	5	8
before sowing	7	7	5	25	10
no answer	2	0	0	0	1

A minority of farmers, particularly in Kiang, apply selection just before sowing and store the harvest un-threshed, which could also be considered unconscious selection for good storability and storage pest resistance. Few other farmers will just keep some millet aside as seed after threshing. Some of the farmers who do not apply selection (they separate seed after threshing) justify this by saying that selection does not matter: you can do good selection, and still have a bad crop the following year. Interestingly, some of these non-selecting farmers also claimed they are approached regularly by other farmers for seed. Farmers applying selection do this because they were taught to do so by their parents, with the idea to maintain good seed quality. Some other farmers mentioned that improving soil fertility is the best way to improve the crop (yield), not via seed selection. They also said that variation in soil fertility is the main factor responsible for differences in the appearance of millet plants.

As in rice, it can also happen in millet that a farmer varies his selection according to particular circumstances. In the case of a bad harvest, for example, everything is harvested together and no selection takes place.

Selection criteria

About 85% of the men (a similar percentage found among women) apply some sort of selection (Table 4.4). In Foni almost all farmers apply some kind of selection (Table 4.4). Interestingly, while percentages of farmers who select are similar, selection criteria differ for *suno*, *majo* and *sanyo* to some extent. The most important selection criterion for all varieties and all areas is spike size. Particularly for *suno*, farmers want to have a big spike (*suno* spikes are usually also longer than *sanyo* spikes). Some farmers mentioned that of each variety sub-varieties exist with long and short spikes and a few farmers said they select for short spikes. Another important criterion is that the spike is well filled (seeds are packed tightly next to each other). Absence of diseases is another criterion, and is particularly important for *majo*. Somewhat less important is seed maturity, although it is much more important in Kiang where farmers grow *suno*. Grain size is important in Fuladu, where farmers cultivate *majo*, and in Kombo, where farmers mostly grow *black sanyo* which is said to have a larger grain than *white sanyo*.

Table 4.4: Percentages of farmers who apply selection and the selection criteria they use, for different millet types and districts; total N = 125 (data from 2002-questionnaire).

	sanyo Kombo	*sanyo* Foni	*majo* Fuladu	*suno* Kiang	total
farmers who do not select	20	3	15	20	15
farmers who select	80	97	85	80	85
selection criteria of farmers who select (N)	45	28	17	16	106
large spike	51	61	53	75	36
many grains	36	54	41	44	27
no disease	29	36	53	50	25
mature grains	24	18	29	50	17
big grain	36	21	53	13	16
right colour	9	7	0	0	2
bristle length	2	0	0	0	0
short spike	2	0	0	0	0

Some farmers in Foni and Kombo said the millet should have the right colour, since colour is an important characteristic to distinguish varieties for taste (see Chapter 5). Very few farmers said they select for long bristles for protection against birds, which is surprising, since so many farmers complain about birds. MJ says bristle length does not matter because he has never seen any *sanyo* without bristles. From the low percentages for the latter two traits it can be concluded that many farmers do not realise that by selecting for long bristles, or for a certain colour, they can manipulate these characteristics. This will be discussed further in Chapter 7.

Comparison of seed samples within varieties

For accessions of the same variety to diverge, genetic variation and selection within accessions are two essential factors. In the introduction it was hypothesised that, hence, it seems unlikely that populations of the same rice variety diverge, whereas for millet, it may be possible for populations of the same variety to diverge. To test this hypothesis, samples of the same varieties from the same village or from different villages were compared in both rice and millet. Because of homonyms and synonyms in farmer nomenclature (see Chapter 6) variety names were not usable to identify varieties and seed samples were considered to represent the same variety only if they did not differ in any qualitative traits.

Rice

Table 4.5 lists the tested rice varieties which showed significant differences among their seed lots. The number of significant differences is very small and not consistent over the years. In the year 2001 the variety *Baraso* (which is actually a formal variety introduced around 1996) showed the highest number of significant differences. In the year 2002 one replication of this variety failed, which might explain the lack of significant differences in 2002. The variety *Barafita Koyo* (a farmer variety obtained in different places) shows significant differences for different traits in 2001 and 2002. For the combined data of both years, only the varieties *Kari Saba* and *Binta Sambou* showed a few significant differences. Of the variety *Kari Saba* one sample had larger seeds than the other 5 samples, but the difference was not big enough to be significant for the separate years. Of the variety *Binta Sambou*, one sample had longer ligules than the other 2 samples, but only when 2 years were combined. The varieties *Mani Wulendingo* and *Sefa Fingo* did not show any differences.

The most likely reason for the inconsistency in significant differences between years is that the trials were set up in newly cleared forest with termite hills and not-level soil, and for some parts of the trial, soil variability was not visible at sowing. Another factor is that because many ANOVA-tests were run, it is likely that some of the significant differences are wrongly identified type I errors. Therefore, it can be assumed that there is an excess in the number of significant differences between seed lots of the same rice variety. Moreover, in all cases the differences are not big and not visible to the eye in farmers' fields. Although the information shown in Table 4.5 is not conclusive, it seems there may be rather little variation at the micro-level, but to be able to estimate the extent of this micro-variation, more research is needed. It can also be concluded that there are no differences in the frequencies with which traits show significant differences (i.e. the frequencies are the same for traits that farmers use as selection criteria and the traits not used as selection criteria).

Millet

For millet, 6 seed lots of *white sanyo* and 3 seed lots of *black sanyo* where compared for 2001, 2002 and for both years combined (Table 4.6). Only seed lots sown in both years were analysed. Analysis shows that there are some significant differences between samples of the same variety, but these differences are not big and not consistent over the years. The samples collected in Tujereng in 2001 and 2002 are different. Analyses show only one significant difference (Table 4.7). The comparisons of the two samples for 2002 are particularly interesting because the farmer who gave us the second sample obtained his millet seed from the first farmer about 12 years ago. The first farmer sows his millet about one month later than the other farmers. If any dissimilarity between millet seed lots were to be expected, it would have been between these two seed lots. Molecular analysis (see Chapter 10) did show a relatively large genetic distance between the two seed lots, suggesting some divergence in process.

Table 4.5: Significant p-values in ANOVA among seed lots of several rice varieties for various traits in 2001, 2002 and both years combined (near to significant p-values are indicated between brackets).

variety	trait	2001	2002	both years
Kari Saba	seed length			**[1]
6 samples	seed width			0.003
4 villages	ligule length	0.031		G×Y interaction[2]
	leaf length			
	leaf width	0.041		
	plant height			
	panicle length			
Barafita Koyo	seed length		0.046	**
3 samples	seed width			
3 villages	ligule length			
	leaf length			
	leaf width		0.033	
	plant height			
	panicle length	0.025		(0.051)
Binta Sambou	seed length			**
3 samples	seed width			
3 villages	ligule length			0.023
	leaf length			
	leaf width			
	plant height			G×Y interaction
	panicle length			
Baraso (Rasi)	seed length			**
3 samples	seed width		(0.058)	
2 villages	ligule length	0.030		
	leaf length			
	leaf width			
	plant height	0.016		G×Y interaction
	panicle length	0.046		
Kumoi	seed length		0.045	**
3 samples	seed width			
2 villages	ligule length			
	leaf length			
	leaf width			
	plant height			
	panicle length			
Bendou	seed length			**
2 samples	seed width	0.009		G×Y interaction
1 village	ligule length			
	leaf length	0.043		G×Y interaction
	leaf width			
	plant height			(0.059)
	panicle length			
Varieties that did not show any differences for any trait:				
M. Wulendingo	2 samples, 2 villages			
Sefa Fingo	2 samples, one village			
# significant differences		8	3	2
% of total number of comparisons		14.3	5.4	4.2

[1] ** = not tested

[2] = Genotype × Year interaction

Comparison of 4 *majo* seed lots yields significant differences for spike length and width (Table 4.7). Farmers indicated that two *majo* varieties exist, one with short spikes and the other with long spikes. The measurements, however, did not agree with farmers' descriptions of the spike length of their *majo* varieties. It is noteworthy to mention that spike width and stem width most often showed significant differences, which may be related to each other (The highest correlation in Table 4.11 is between spike width and stem width). These findings suggest that selection pressures may result in relatively small genetic changes of millet seed lots.

Table 4.6: Significant p-values in ANOVA for seed lots of two millet varieties for several traits in 2001, 2002 and both years combined (near to significant p-values are indicated between brackets).

variety	trait	2001	2002	both years
black sanyo from	plant height			
Faraba	spike length			
3 samples	spike width	(0.063)		0.004
1 village	leaf length			
	leaf width			
	stem width			
	separation	0.015		GxY interaction[1)]
white sanyo from	plant height	0.042		GxY interaction
Janack and Kitti	spike length	(0.058)		
6 samples	spike width	0.009		
2 villages	leaf length			
	leaf width		(0.052)	
	stem width	0.029		0.049
	separation			
# significant differences		4	0	2
% of total number of comparisons		28.6	0.0	14.3

[1)] = Genotype × Year interaction

Table 4.7: Significant p-values in ANOVA for several traits for seed lots of two millet varieties.

trait	*black sanyo* from Tujereng, 2001 (6 samples)	*black sanyo* from Tujereng, 2002 (2 samples)	*majo* from Damphakunda and Sanending, 2002 (4 samples)
plant height			
spike length			0.023
spike width			0.012
leaf length			
leaf width	0.028		
stem width			
separation			
# significant differences	1	0	2
% of total number of comparisons	14.3	0.0	28.6

Wide sense heritability

Since the results presented above show no big differences between seed lots within varieties, a question that needs to be answered is whether selection actually has any effect. Therefore, the data of the rice and millet trials for morphological comparisons were used to estimate wide sense heritability (Table 4.8). Wide sense heritability[7] can be described as a rough measure to estimate the level of heritability of a particular trait. Heritability estimates can range between 0

[7] More precise estimations, narrow sense heritability, can be obtained through the comparison of the progeny of a cross of two genotypes.

and 1. The higher the figure, the more efficient selection can be. For rice, the farmer varieties from clusters II and III (Figure 10.3) based on molecular data were used and, for millet, only those accessions of *white sanyo* were used that were included in both trials of 2001 and 2002.

For most traits of rice, wide sense heritability estimates are relatively high for both years, separately and combined. The estimates are highest and most stable for 100 seed weight and seed width, followed by seed length and # days to 50% flowering. The relatively low values for seed length in 2001 are caused by less precise measuring than in 2002. The relatively low values for panicle length are somewhat surprising since it is one of the most important selection criteria used by women for rice.

For millet, wide sense heritability estimates are lower when compared to rice, because of the small differences between seed lots. For millet, differences in heritability estimates are larger between years and between traits, compared to those for rice. Particularly the values for the single years and the values for the 2 years combined differ more, which is probably caused by G × Y interactions due to differences in trial conditions between the 2 years. When both years are combined, the values for spike length, spike width and days to 50% flowering are clearly higher than the values for the other traits, while for the 2 separate years values for spike length, spike width and days to 50% flowering are more similar to those for the other traits. This suggests that spike length, spike width and days to 50% flowering differ relatively little between years and that selection for these traits will be more effective than for any of the other traits.

Table 4.8: Wide sense heritability estimates of rice and millet based on single-location trials over 2 years.

	rice						*millet*		
	2001		2002		2 years		2001	2002	2 years
# varieties	6[1]	8[1]	6	8	6	8	1	1	1
# seed lots							6	6	6
plant height	0.30	0.34	0.67	0.84	0.74	0.83	0.72	0.43	0.00
panicle length	0.82	0.00	0.49	0.52	0.80	0.42			
spike length							0.68	0.17	0.38
spike width							0.83	0.47	0.73
leaf length	0.44	0.64	0.00	0.14	0.73	0.91	0.26	0.47	0.00
leaf width	0.85	0.00	0.84	0.86	0.83	0.52	0.27	0.66	0.00
stem width	n.a2)	n.a.	n.a.	n.a.	n.a.	n.a.	0.75	0.59	0.16
ligule length	0.71	0.68	0.66	0.46	0.66	0.51			
separation							0.00	0.00	0.00
seed length	0.61	0.60	0.91	0.96	0.87	0.84			
seed width	0.98	0.85	1.00	0.96	1.00	0.90			
DAS 50%flowering [3]	0.76	0.94	0.63	0.87	0.77	0.87	0.68	0.73	0.36
100(0) seed weight [4]	0.98	0.90	0.98	0.86	1.00	0.99	0.31	0.00	0.23
# panicles / plant [5]	0.51	0.00	0.63	0.36	0.83	0.10	0.00	0.00	0.00
plot yield	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	0.52	0.58	0.00

[1] The 6 and 8 farmer varieties belong to clusters III and II respectively (Figure 10.3)
[2] n.a. = not available
[3] Days after sowing till 50% flowering
[4] 100 seed weight for rice and 1000 seed weight for millet
[5] # spikes / plant in the case of millet

For millet, wide sense heritability estimates are also calculated with the data from a 4-location trial (for trial set-up, see Chapter 11). The estimates of wide sense heritability vary a lot from site to site, which indicates that the selection efficiency will differ between places (Table 4.9). For example, the high value for spike length and width in Faraba indicates that selection will be effective for both spike length and width in Faraba, whereas the low values for spike length in Janack and Kitty indicate that the same selection in these places will not be effective. Furthermore, selection for leaf width (should any farmer have an interest in selecting for leaf width) would be most effective in Tujereng, whereas selection for leaf length might be more effective in Faraba. In general, selection for spike length and spike width will be more effective than for any of the other characteristics, which is in accordance with the information from the heritability estimates based on two years.

Table 4.9: Estimates of wide sense heritability for various traits of millet, per village and for four villages combined, based on data of one year.

site	plot yield	leaf length	leaf width	# spikes / plant	spike length	spike width	plant height
Faraba	0.00	0.45	0.00	0.00	0.87	0.85	0.91
Janack	0.68	0.00	0.52	0.43	0.00	0.61	0.77
Tujereng	0.13	0.00	0.87	0.33	0.46	0.40	0.87
Kitty	n.a. 1)	0.00	0.28	0.00	0.29	0.91	0.00
villages combined	0.00	0.43	0.77	0.36	0.90	0.97	0.76

1) n.a. = not available

Correlations

Correlations were calculated on individual plant data because, particularly in the case of millet, plants within the same plot differ a lot in stature. Table 4.10 shows that, for rice, plant height is highly correlated with leaf length, panicle length and to a lower degree with leaf width. Leaf length also shows a clear correlation with panicle length and leaf width. So, if women select tall off-types with long panicles, it is likely that they will also select for long, wide leaves at the same time, which are important traits for the weed suppression capacity of rice.

Table 4.10: Pearson correlations of various plant characteristics of rice accessions (only *O. sativa*) based on individual plant measurements (N ranges from 1471 to 1620) of 90 accessions of the 2002-trial.

	panicle length	leaf length	leaf width	ligule length	stem width	# panicles / plant
plant height	0.62	0.72	0.53	0.22	0.35	-0.01
panicle length		0.57	0.40	0.16	0.28	0.00
leaf length			0.54	0.15	0.34	-0.11
leaf width				0.05	0.51	-0.24
ligule length					0.01	0.15
stem width						-0.17

Compared to rice, correlations for millet are very low, and the highest values are for the correlations of stem diameter with spike width, and leaf width, respectively (Table 4.11). Although the correlations are relatively low, selection for big spikes (long, wide spikes) might result in indirect selection for thick stems and long, wide leaves. Indirect selection for plant height or for number of tillers per plant, however, by selecting long, thick spikes will be an inefficient process.

Table 4.11: Pearson correlations of various traits of millet based on individual plant measurements (N ranges from 347 to 392) of 20 accessions of the 2002-trial.

	spike length	spike width	leaf length	leaf width	stem width	separation	# tillers / plant
plant height	0.04	0.03	0.18	0.12	-0.14	0.36	0.27
spike length		-0.04	0.25	-0.01	0.26	0.10	-0.01
spike width			0.12	0.29	0.45	-0.10	0.02
leaf length				0.26	0.27	0.09	0.07
leaf width					0.41	-0.11	-0.02
stem diameter						-0.18	-0.06
separation							0.02

4.4 Discussion

The main questions dealt with in this chapter are whether farmer seed selection, social, agronomic and ecological factors exert or result in some kind of directed selection pressure and whether that results in differences between seed lots of the same variety. The discussion answers these questions first and then looks at comparable case studies on genetic divergence in rice and millet.

Farmer seed selection

The reason behind seed selection, for both men and women, is not to improve varieties but to get good quality seed to ensure good germination. This is in accordance with other studies (Almekinders *et al.*, 1994; Louette and Smale, 2000). A general statement often made is that farmers select seed for the next season from the superior plants within varieties (Wood and Lenné, 1997). Because the differences between small and big rice panicles are rather small and difficult to see in the field, and because a large number of panicles (20,000 panicles for 40 kg of seed) is needed to get a sufficient amount of seed, seed selection for rice at panicle level is just not feasible. Women try to minimise the number of off-types and mixtures in their seed, but thorough seed purification is a very tedious job, and very few women have the time to do that. As a result, it is common that off-types remain in the seed. However, women do select off-types they are not familiar with, which they develop into new, better varieties. This will be discussed in detail in Chapter 7. The selection of off-types is, next to ensuring good seed quality, the second purpose of seed selection. Women do not try to improve their seed stock through selection within varieties. Contrary to rice, it is possible for millet to select between spikes because differences between spikes are very obvious and the average farmer only needs about 1000 spikes for sufficient seed. Selection could be more effective for millet without bristles, but farmer selection practices are the same for all millet types.

For seed selection of both rice and millet, farmers only consider traits related to the inflorescence, but no vegetative traits. Theoretically, selection before the actual millet harvest would be best, but men do not do this because the leaves itch and can cut their skin easily. Farmers also said that there is no relation between vegetative traits and good seed. In theory, farmers could also select earlier or later maturing plants, or select for some other traits. In Kombo, where men often mentioned that seed colour is important, men said they do not apply strict selection on colour, because the colour can change from black to white and vice versa. Selection is about ensuring good seed quality. A farmer who grows black millet and sees a very nice well-filled big spike with big white grains will also add it to his seed.

For other crops like maize and sorghum, Gambian farmers also only use inflorescence-related traits for seed selection. This is in accordance with many other studies on seed selection. In

Rajahstan, India, farmers also use the traits of the spikes of millet for seed selection (Dhamotharan *et al.*, 1997). In Mali, however, farmers select the most vigorous, healthy plants with the most beautiful spikes (Sandmeier *et al.*, 1986). For maize, many studies show that farmers' seed selection criteria are related to the traits of the inflorescence (Louette and Smale, 2000; Bellon and Brush, 1994; Rice *et al.*, 1998). In the case of sorghum in Zimbabwe and Sudan, farmers select the best sorghum plants in the field and harvest these separately before the main harvest (Harlan, 1975; Mushita, 1993; Berg, 1993). However, most farmers in Ethiopia select seed of sorghum after harvest (McGuire, 2005).

Social factors

Whether farmers can and do select superior plants for seed depends on the specific morphological characteristics of a crop in combination with socio-cultural understandings. The reasons why farmers often do not follow the recommendations to select healthier and shorter maize plants (Bellon and Brush, 1994) or maize plants with many tillers (Smith *et al.*, 2001) are probably related to these socio-cultural understandings of seed. Smith *et al.* (2001) argue that if farmers select maize plants with many tillers they likely can improve the yields of their varieties. In the case of millet, high tillering is also positively related to drought avoidance (Van Oosterom *et al.*, 1996; Vom Brocke *et al.*, 2003), and, indirectly, should also have a positive impact on yield.

Bradshaw (1975) argues that different cultural traditions can select for different genotypes[8] in regions that are environmentally similar, and that this has happened with cotton in Central America. It also seems to apply to millet in Western Division in The Gambia where traditionally Jola prefer white millet and Mandinka prefer black millet. So, indirectly, social understandings seem to exert a selection pressure through farmer seed selection criteria.

Social factors also indirectly exert a certain selection pressure because of the influence they exert over farmer crop management. For both millet and rice, farmers sometimes change selection practices in adjustment to particular socio-economic conditions, like labour shortages and illness, even within a single season.

Gender does not seem to be a factor in selection practices within varieties. There is no clear evidence that selection practices of men and women within the same compound are distinct. Moreover, men and women agreed that selection for rice and millet is the same and that they would look for the same desired traits. For millet and rice, respectively, most men and women select their seed during harvesting and the selection criteria they use are similar. Furthermore, selection practices differ more between early and late millet, than between rice and millet. Hence, it seems clear that any differences in seed selection are related to differences in the plant morphology of rice and millet rather than to gender.

It seemed logical, at first sight, that women, who need to do compound work as well as farm work, will lack time to do proper selection. However, no significant relationships were found. This actually indicates the importance of seed selection in Gambian rural communities. Although there is no clear relationship between age and selection practices, there is a tendency, for both men and women, for older people to do seed selection at a later stage; people who set aside seed after threshing tend to be older people.

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[8] Strictly speaking, farmers only select for different phenotypes, but as phenotypes and genotypes are related, particularly under environmental homogeneous conditions ($P = G + G \times E + E$), selection for different phenotypes results in the development of different genotypes.

Vicinity to urban areas has no impact on farmers' selection practices, although it does have on seed storage (see Chapter 3). In Kombo farmers in general think millet is less important than in the areas far away from the urban areas and in Kombo they often grow smaller fields of millet, but this difference not withstanding there is no clear difference in seed selection. Neither does the possibility of having other income sources have any clear relationship with farmers' selection methods. To farm, is to select.

Although it is difficult to find proper indicators, from informal interviews it became clear that some farmers have a greater interest in testing different varieties and selection methods than other farmers. This was also suggested by Prain (1994). The interest of farmers might have a bigger impact on farmer seed management and seed selection than any other well defined social factors.

Agronomic factors

For millet, farmers exert a tacit selection pressure through their farming practices. In Chapter 3 farming practices for millet were described. The most obvious practice that has a selective effect is the harvesting of the millet. During harvesting, most spikes that shatter their seeds and the small spikes with few seeds are left behind on the ground, which means that much weedy millet does not end up in the seed or the portion of the harvest meant for consumption (see Chapter 8). Another practice is the thinning of millet, when the least vigorous plants are removed. The clearest difference is between early and late millet: a larger number of plants are left per hill for early millet than for late millet. Differences between farmers growing the same variety of millet are not big.

Different sowing methods lead to differences in plant density. Stands of early millet tend to be denser than those of late millet and late millet sown by hand tends to have a lower plant density than late millet sown by machine. During domestication, the number of tillers and the number of inflorescences became reduced in pearl millet, sorghum, maize and sunflower (De Wet and Harlan, 1975). In farmers' fields, competition between plants plays an important role, because the taller plants have an advantage over the shorter plants. So, the question needs to be answered whether high plant densities have a positive selective effect on plant height, tiller number and spike size. The millet seed lots from Tujereng, where farmers in general use low plant densities, are shorter in height than the seed lots collected from other villages.

The number of weedings varies between farmers, but can also vary per farmer from year to year, depending on conditions. The use of fertiliser and cow dung also varies between farmers, but the question is how much effect this has since farmers often use low quantities of fertiliser and there is much variation within fields. Often, farmers use the better part of the field for seed. This means that selection pressures and consequently the genetic make-up of varieties (of millet particularly) might change from year to year, but probably not in a linear way.

The farmers whose farming practices are clearly different are very few. In Tujereng there is one farmer who sows his millet much later (3 weeks) than other farmers, and because of this his millet is exposed to somewhat different environmental conditions than that of other farmers. Molecular analysis in Chapter 10 showed a relatively large genetic distance between his seed lot and that of another farmer with 'normal farming practices' who had obtained his seed from the first farmer about 12 years earlier.

Ecological factors

Compared to other countries, The Gambia is very flat and, except for inland valley swamps, it is not common to find several different micro-climates in the same area (see Chapter 3). At country level there are several agro-ecological zones, as explained in Chapter 2. For millet, natural selection pressures will usually be the same for all fields of one village, the surrounding villages and perhaps even further. While agronomic practices can function as divergent selection pressures within a village, natural selection pressures do not. It is clear that many ecological factors vary a lot from year to year, including rainfall and prevalence of pests and diseases. This means that selection pressures and consequently the genetic make-up of particularly millet varieties can change from year to year, but probably not in a linear way.

The ecological factors that have the biggest influence on the genetic make-up of millet varieties are likely to be the amount of rainfall and the prevalence of blister beetles. As explained in Chapter 2, rainfall decreased in the early 1970s, and it is likely that this factor helped change millet populations. However, rainfall did not decrease in a regular way, but in an irregular way with extremes going both ways (see Figure 2.5). This implies that a period of many years will be needed for millet populations to adapt to a lower rainfall regime.

Blister beetle has an opposite effect in early and late millet. In early millet, the blister beetle sucks the seeds empty of the late flowering plants at the end of the flowering period, whereas in late millet, the seeds of the early flowering plants are sucked out. It happens sometimes that a few plants are intermediate in flowering, but blister beetles effectively prevent mingling of early and late millet populations.

Other pests and fungi can also exert selection pressures, but to be able to say more about this, further research is needed. The results of the soil analysis done in the 4 villages of Tujereng, Faraba, Kitty and Janack to compare millet fields (see Chapter 3) showed that the differences between millet fields are very small. An extended soil analysis (Dunsmore *et al.*, 1976) shows Gambian soils are quite homogeneous at the macro-level.

Differences between seed lots of the same varieties

When comparing crops, it becomes clear that millet, like maize, is quite an exception, because in these two crops, farmer selection theoretically is able to change the genetic make-up within varieties. For groundnuts and rice, farmers can at most only discard the few diseased and small plants with few seeds (so-called negative bulk selection). For rice, differences between panicles are rather small and effective selection is therefore not feasible. Many cereals, such as wheat, barley, oat and rye, have a similar plant morphology to rice. For sorghum, a similar selection might be applied as for millet, and therefore sorghum can be grouped with maize and millet.

Farmer rice varieties are genetically homogeneous (see also Chapters 7 and 10). Hence, it is unlikely that varieties or seed lots change due to selection pressures exerted by farmer seed selection, agronomic factors or ecological factors. To a large extent, this agrees with the information presented on differences between rice seed lots in this chapter. It is plausible that genetic divergence within rice varieties only occurs as the result of extreme ecological selection pressures, which cause genetic bottlenecks. If population sizes are small, divergence can occur more easily (Slatkin, 1987).

The information collected in this chapter suggests that rice varieties rarely change genetically, and that if they change, it is due to extreme ecological selection pressures. Tin *et al.* (2001) argue that the changes they found in rice varieties over time are the result of adaptation to changed farming system and include natural and farmers' selection over time. They explain that, because of a more reliable water supply, farmer managed varieties flower and mature later than the gene-bank populations. However, they mention that after 1991, farmers started using single-plant selection. Another change that was mentioned is that farmer-managed populations on average contained fewer off-types than the gene-bank material. It is quite common for farmers to donate contaminated seed to other farmers (Richards, 1986; Jusu, 1999) and it might have happened that farmers gave contaminated grain to the gene bank instead of seed. From the study done by Tin *et al.* (2001), it remains unclear to what extent their results can be attributed to differences in off-type proportions and changes in selection practices. Apparently, the results are also somewhat surprising to Tin *et al.* (2001) themselves because they write: 'In this case such changes have happened surprisingly fast'. So, when studying landraces and populations of farmers' varieties, it is very important to clarify the variation within landraces and populations and to standardise concepts, otherwise the actual causes of observed changes remain unclear.

For millet, only a few significant differences were found between seed lots within varieties. Both morphological and molecular analyses (see Chapter 10) showed that seed lots of the same millet variety grown in the same village differed more than, or as much as, seed lots of the same variety grown in different villages. This suggests that farmer selection and agro-ecological conditions can differ as much within as between villages. In Chapter 7, it is concluded that there is no effective pollen flow between seed lots and the information in Chapter 6 suggests that, although farmers sometimes do replenish their seed stock, this does not happen regularly. Many of the farmers from whom I obtained seed said that they did not borrow seed from other farmers over a long period of time. Farmers collect millet seed from a large number of spikes, making genetic drift very improbable.

In a case study on millet in Rajasthan, Vom Brocke *et al.* (2003) also found that intra-village variation was higher than inter-village variation in western Rajasthan, and, in addition to similarity of habitats, offered seed flows and diversity in seed selection practices as possible explanations. Farmers in Rajasthan cultivated both formal and farmer varieties and often mixed seed of farmer varieties and formal varieties. Vom Brocke *et al.* (2003) also added that the selection effects were generally small.

Plant populations with some cross-pollination that have been completely isolated for long periods often show little differentiation, while populations may differentiate if they are subjected to different selective forces (Ehrlich and Raven, 1969). Bradshaw (1975) argues that if cultural practices are similar over large areas, selection will be uniform and can act against divergence due to natural selection pressures. Agro-ecological selection pressures are directed to traits like flowering period, drought tolerance, disease resistance, seed production and other traits that maximise chances of survival. Farmer selection is only directed to spike related traits. The wide sense heritabilities calculated for the various traits of millet indicate that the traits for which farmer selection is most effective are spike length, spike width and 1000-seed weight, but that the selection effect can also differ between years and places. The correlations between the various traits are too low for effective indirect selection and, hence, it is unlikely that selection for spike size (i.e. length and width) will lead to differences between lots for other traits. This means that agro-ecological selection pressures are directed to both vegetative and reproductive traits, while farmer selection is only directed to the reproductive traits.

The efficiency of farmer seed selection in millet was not studied and consequently it is not possible to say whether farmer variety development in millet is largely a conscious or unconscious process. Studies conducted by Soleri *et al.* (2000), Smith *et al.* (2001), Dudley *et al.* (1974) and Chandhanamutta (1971; in Frey; 1990) also show that it is not possible to give any indication of the effect of selection based on a 2-year study. To be able to disentangle the relative effects of the various factors, research over a period of at least 10 generations is necessary. Another question that should be answered is whether the populations within which farmer selection takes place differ in diversity over the long run from populations in which improved scientific selection takes place.

4.5 Conclusions

The following conclusions can be drawn:

- Any differences in farmer selection practices in rice and millet are related to plant structure and not to gender. For both crops, farmers consider only inflorescence related traits.
- Farmer seed selection is intended to ensure good germination quality of the seed, not improvement of the genetic quality of varieties.
- Differences within varieties of rice and millet are very small; the differences within rice varieties found in this study might also be due to experimental errors, while differences within millet are probably the result of various selection pressures.
- Given the heritability estimates for the traits farmers consider during selection, farmer seed selection can theoretically lead to genetic improvement of populations for both crops. Taking into account farmer seed selection practices for both crops, in practice, genetic improvement is only possible for millet.
- Although particular farming practices theoretically might exert a linear selection pressure on millet populations, farming practices in their entirety result in a multi-directional selection pressure.
- Ecological conditions between years vary too much for divergent selection in millet.
- Geographical and ecological variation is rather limited in The Gambia and exerts little divergent selection in millet populations.
- Millet seed lots do diverge, but not much and it is unlikely, or rare, for new millet varieties to develop in this way.
- Whereas for millet, farmer varieties may adapt to changing conditions over time, this is less likely for rice. If conditions change for rice, farmers need to find other varieties to replace the current ones. Hence, for rice, farmer variety development is a ‘stop-and-jump’ process, while, for millet, farmer variety development may be better regarded as a slow and relatively smooth on-going process.
- To achieve a better understanding of the effect of farmer selection and agro-ecological selection pressures on millet populations (and other crop populations) continuous research over a period of at least 10 years is now needed.

5 Farmer variety use and management

5.1 Introduction

Whereas the previous chapter focused on selection within varieties, in this chapter farmer selection between varieties (variety choice) is discussed. An important reason for farmers to use various varieties is ecological variation (Bellon, 1996; Louette *et al.*, 1997; Richards, 1986). However, in the Peruvian Andes, where potatoes are the main staple food, farmers do not match varieties to specific ecological conditions, although they use a wide range of varieties (Zimmerer, 1998; Brush, 1995). Consequently, the agronomic advantage of the large diversity in Peruvian potato is difficult to ascertain (Brush, 1995). Another reason for farmers to use various varieties is the wide range in use purposes. Use purposes include culinary, cultural and market preferences regarding taste, colour, seed size, cooking time and processing quality (Almekinders *et al.*, 1994). In Sierra Leone farmers use several rice varieties of similar duration because of differences in processing, keeping quality or as insurance against disease risks (Richards, 1996a). In Mexico farmers use many maize varieties because none of the varieties meet all the selection criteria (Brush, 1995; Rice *et al.*, 1998). Hence, variety choice can be considered a process in which farmers match bundles of traits with agronomic conditions, consumption preferences and marketing requirements (Bellon and Smale, 1998). The more selection criteria farmers have, the higher the number of varieties they use (Teshome *et al.*, 1999).

Various other factors also influence variety choice. In the case of potatoes in the Peruvian Andes, varietal diversity is also used for cultural and social purposes (Brush, 1992). In turn, cultural importance determines how carefully people look at plants and animals and how many varieties they distinguish (Boster, 1985). In sharp contrast to the large diversity that can be found in potato fields in the Peruvian Andes (Zimmerer, 1998), in Kwazulu Natal, in South Africa, potato is a relatively new and uncommon crop and farmers only grow one variety of potato (Nuijten, unpublished). Crop diversity is also maintained to keep future options open, as an insurance against changing environmental and socio-economic conditions (Dennis, 1988; Almekinders *et al.*, 1994). The number of varieties grown by farmers is also related to the available labour (Zimmerer, 1991; Richards, 1986). Hence, in certain farming systems variety choice is more complex than as formulated by Bellon and Smale (1998).

As a result, farmers in low-input farming systems often use a wide range of varieties for various crops: Maize in Mexico (Louette *et al.*, 1997; Bellon, 1996), potato in the Peruvian Andes (Zimmerer, 1998; Quiros *et al.*, 1990; Brush, 1995), sorghum in Ethiopia (Teshome *et al.*, 1997; McGuire, 2005), cassava in Peru (Boster, 1985), beans in Central Africa and Malawi (Voss, 1992; Sperling *et al.*, 1993, Martin and Adams, 1987). Also for rice and millet, various studies identified the use of large numbers of varieties. In one Indonesian village 49 rice varieties were identified (Lambert, 1985) and in one chiefdom in Sierra Leone farmers differentiated between 70 rice varieties (Richards, 1986). A study on 8 villages in an area near Chiang Mai in Thailand showed that the number of rice varieties used per village varied from 3 to 30 and that overlap between these villages differed considerably (Dennis, 1988). In Niger, one of the countries belonging to the presumed centre of origin for pearl millet, it was found that 33 varieties were grown in 58 villages (Ndjeunga, 2002). In a large survey in central Burkina Faso 90 landraces of pearl millet were collected (Wilson *et al.*, 1990).

Whereas before, it was often thought that farmers preserve a static portfolio of crops and crop varieties, nowadays, a more common view is that they import and discard diversity in a dynamic fashion, according to their needs in any given period of time (Cromwell and Van Oosterhout, 1999). Hence, the range of crops and crop varieties, both farmer and formal varieties, might be broadened or narrowed according to the economic, socio-cultural and environmental circumstances of the individual farmers (Cromwell and Van Oosterhout, 1999).

This chapter describes farmer variety use and management, such as the number of varieties used, variety choice, changes in variety portfolios and variety replacement. Information on variety and seed exchange (gene flow through seed) directly affected by farmer variety management is presented in Chapter 6. The number of varieties in a village gives some information about crop diversity at village level. Chapter 10 describes more in detail the genetic diversity represented by varieties between villages.

Since millet is an outbreeder grown by men and rice an inbreeder grown by women, one main research question treated in this chapter is whether and how breeding system influences farmer variety management and portfolios. It is hypothesised that fewer millet varieties are liable to exist than rice varieties. Because of their different breeding systems, the characteristics of millet genotypes will mix more easily than the characteristics of rice genotypes, resulting in a smaller number of millet varieties. A second research question is which and how agro-ecological and socio-economic factors influence variety management. Other issues discussed are the extent of cultivation of formal rice varieties and the traditional African rice (*O. glaberrima*) by Gambian farmers.

5.2 Methods

Using a questionnaire in 2002, information on variety management was collected in 11 villages, spread over the South Bank (Figure 1.1). This information is combined with data collected in Tujereng from 2000 to 2003. Each year the same farmers were asked the same set of questions on variety management. Some of these farmers were interviewed in depth about the origin and use of *O. glaberrima* and the dynamics of variety use in the past.

On the basis of semi-structured interviews conducted in the four villages Tujereng, Faraba, Kitty and Janack in 2000, the morphological and molecular analyses of the rice and millet samples collected in these villages (see Chapter 10 for results) and information obtained from various people working for formal institutions an almost complete picture of the use of formal varieties in these four villages is drawn.

5.3 Results

Number of rice and millet varieties used by farmers

There is a very large difference in the number of varieties identified for millet and rice during the survey in 2002. For rice, in total 112 varieties were identified, and likely the actual number of rice varieties in the surveyed villages is even higher (Table 5.6). The total number of millet varieties found in this study amounts to 6, of which 4 are late millet (see also Chapter 10) and 2 are early millet. On average, each woman uses 3 varieties of rice and ranges from 1 to 11 (Table 5.1). Men normally use one variety of millet. Very few men use a mixture of two varieties.

There are many factors contributing to the difference in number of rice and millet varieties used. Male and female farmers were asked what they think are the reasons that women use so many rice varieties and men only so few millet varieties (Appendix 3). Many did not have any idea; some said ‘that is the way it is’ or ‘more rice varieties exist than millet varieties’. The answers given by other farmers can be related to differences in rice and millet cultivation and crop characteristics. Many men and women indicated that millet is more drought resistant, and by planting more varieties of rice the risk of crop failure in rice is reduced. Some men also said that because of birds, the choice of millet varieties is reduced. A few men said the variety they grow is the only one available. Some women mentioned that there are more distinct ecologies for rice than for millet or that, for rice, long and short duration varieties exist. One man said that all millet varieties mature at the same time, unlike rice. Apparently this man forgot about the difference in flowering of early and late millet. A few men also said that their labour force was limited, so it was not possible to grow two varieties, although the average labour force for men is larger than that for women (see Chapter 2). A few men also said that millet is more difficult to cultivate than rice (an interesting comment because millet is drought and weed tolerant and needs less labour than rice). Some women and one man also said that women grow many varieties to be able to look for the best varieties, while men do not. One woman said that rice varieties are given names, while millet is just millet. One man also said that they depend on rice more than on millet. Finally, one woman also said that many new varieties come out from rice, which does not happen for millet.

It can be concluded that a lot of people try to answer this question by saying 'it has always been this way', or by relating the number of varieties used to the different ecologies, cultivation practices and characteristics of the two crops. Some women mention that the attitude of women differs from men, because women look actively for better varieties. Only one woman (out of 134) mentioned that many varieties come out from rice. This, however, was also mentioned sometimes in other interviews (to be discussed in detail in Chapter 7).

As farmers say, for millet, the differences between the various ecologies are much smaller than for rice. The total number of ecologies for millet is three, whereas for rice four main ecologies can be identified, which can be subdivided into many sub-ecologies (see Chapter 3). Moreover, for millet, one ecology can cover several districts, but for rice, several ecologies can often be found in one village. This means that there is a bigger need to match the right variety to the right ecology for rice than for millet.

Differences in number of rice varieties used by farmers between ecologies and villages

Variety choice is thus more complex for rice than for millet. Furthermore, the number of rice varieties a farmer uses can differ between ecologies and even between villages in the same ecology. The two most apparent factors explaining this variation are the ecological variation in a village and the space available for rice cultivation. In many villages women have several rice fields, sometimes in different ecologies, but even fields situated in the same ecology can still differ ecologically. In the past, women cultivated rice in several ecologies in almost all villages, but because of the decrease in rainfall women have had to abandon certain areas, usually the uplands. Farmers who work in two ecologies tend to use more varieties than farmers who only work in one ecology, particularly in Kombo (Spearman's rho = 0.338, $p = 0.000$; N = 137).

Women who have bigger fields use more rice varieties (for farmers who work in one ecology, Pearson correlation = 0.229, $p = 0.024$; N=97; for farmers who work in two ecologies, Pearson correlation = 0.440, $p = 0.012$; N= 32). In Kiang, where farmers grow big fields (Table 5.1), farmers have several fields in 'the same ecology': some fields are shallow flooded, while others are deep flooded and require different varieties. Some women in Tujereng who grew fewer varieties in 2002 compared to 2001 explained they reduced the number of varieties because of smaller fields in 2002: if the field becomes too small, it is better to discard one variety than to allocate a very small area to each variety.

Table 5.1: Main rice ecologies per village, # respondents working in 1 or 2 ecologies, average number and range of rice varieties cultivated per village, field size and average area per variety (in ha) (data from 2002-questionnaire).

village	rice ecology[1)]	respondents[2)] (N)	average # varieties 1 eco[4)]	average # varieties 2 eco	range of varieties	field size (in ha)	area / variety (in ha)
Jiroff	mangrove	10	3.4		2-5	1.4	0.4
Massembeh	mangrove	7+3	4.1	4.0	3-5	1.6	0.5
Batabut	lowland	9	2.0		1-5	0.6	0.3
Kartung	lowland	9	2.9		1-6	0.5	0.2
Sanending	lowland	10	2.6		1-4	0.3	0.1
Faraba	lowland + trans zone[3)]	6+12	2.7	4.5	2-8	0.7	0.2
Kitti	lowland + trans zone	7+11	2.4	4.5	1-11	0.8	0.2
Damphakunda	trans zone	8+2	1.9	2.0	1-3	1.3	0.7
Sangajor	trans zone	10	2.6		2-5	1.2	0.5
Janack	upland / trans zone	8	3.8		2-7	0.6	0.2
Tujereng	upland / trans zone / lowland	19+1	2.9	7.0	1-7	0.4	0.1

1) = Most common ecology in the particular villages; + = many farmers work in both ecologies; / = farmers grow in either one ecology. Lowland (except in Tujereng) is used to indicate areas where rice is mostly transplanted; in the transitional zone rice is mostly broadcasted.
2) = The first number indicates the number of respondents working in one ecology; the 2nd number indicates the number of respondents working in 2 distinct ecologies
3) trans zone = transitional zone; 4) eco = ecology

The effects of other factors, such as citizenship, landownership and ethnicity, seem to be different between the uplands and lowlands and even between villages sharing the same ecology, which makes it difficult to generalise. Further, the numbers of interviewed farmers working in the uplands and mangrove associated lowlands are relatively small, making a good comparison between ecologies difficult.

Therefore, the comparison below emphasises the lowlands where farmers broadcast and the lowlands where farmers transplant rice in Western Division. Table 5.2 shows that those farmers who grow rice in two ecologies use the highest number of varieties. These farmers also tend to use larger areas. Other differences in Table 5.2 are less easily explained.

Strangers tend to grow more varieties than founders (for definitions, see Chapter 1) in the lowlands where rice is broadcast, while in the areas where rice is transplanted, founders tend to grow more varieties (Table 5.2). As is shown in Table 2.9, both strangers and founders have usufruct rights on land in most districts, except in Kombo where many strangers do not have usufruct rights. Farmers who do not have usufruct rights depend on borrowing land from other farmers. A possible complicating factor is that, in such cases, farmers never know for how long they can borrow a field, because they know the farmer who lends it to them can ask for it anytime. In such a situation it is better to have a wide set of varieties at hand, to be sure to have some varieties to match the right conditions. However, among those farmers transplanting rice, those who have usufruct rights tend to grow more varieties than those who do not have such rights. This difference is caused by the fact that the farmers transplanting rice and not having usufruct rights (except one) come from the village of Batabut, where farmers, on average, use a limited number of varieties (Table 5.1).

Although it seems there are some trends, no clear differences can be observed in the number of varieties used by different ethnicities. The trends in Table 5.2 are caused more by specific conditions in the sampled villages than ethnicity. This is in agreement with the finding that in

Casamance the Mandinka and Jola rice production systems differ in labour divisions and ploughing techniques, but not in variety management (Osborn, 1990).

Table 5.2: Average number of rice varieties per ecology, by origin of farmer, land usufruct rights and ethnicity, for only those sampled villages in Western Division where rice is cultivated in the lowlands and transitional zone (data from 2002-questionnaire).

	faro, sown		*faro, sown and planted*		*faro, planted*	
	mean	N	mean	N	mean	N
origin						
founder	2.4	17	3.5	10	3.2	9
stranger	3.5	11	4.8	10	1.9	7
usufruct rights						
does not have	4.0	7	4.4	8	1.8	4
does have	2.5	24	4.6	15	2.8	13
ethnicity						
Mandinka	3.1	15	4.6	16	3.4	7
Jola	2.7	15	4.4	7	2.0	10

Variety choices

Rice

For rice, number of days to maturity is the most important variety criterion. It is important that varieties are not too early to avoid bird damage, and not too late to assure the crop will mature. In Western Division the rainy season starts in late June and ends early October, 3½ months later (see Table 2.11). At the same time, some women try to grow varieties with a different duration to spread labour at harvesting time. Apart from that, differences in duration also reduce the risk of total crop failure. In general, women say they prefer varieties with big panicles and big seeds. But particularly in the uplands and transitional zones, varieties that perform well often have small seeds. In effect, this means that women prefer good yielding varieties with small seeds to varieties with big seeds but poor yield. Plant height is another important criterion. In the lowlands it is important for rice plants not to get completely submerged. In the uplands women prefer tall varieties to make harvesting with a knife easier. Short varieties can be harvested quite easily with a sickle, but women say they are not used to sickle harvesting. Another advantage of tall varieties in the uplands is that they are not as easily overgrown by weeds as short varieties because timely weeding is often a problem in the uplands. Very early varieties also have the disadvantage they might flower before weeding is finished. Taste is also an important characteristic, but sometimes leads to disputes between women. It is quite interesting that varieties with a good taste belong to the *japonica* subspecies. These varieties combine good taste with large seed size. The large seeded variety *Kukur* is often mentioned as ideal for *dempetengo* (a snack prepared by roasting almost mature fresh rice in a pan on a fire). The variety most preferred for its taste is actually a variety with small slender seeds, called *Mani Wulendingo*. Farmers say it is ideal for *benechin* (Wolof dish; rice is boiled in a mixture of water, oil and condiments). Of imported rice, most people in The Gambia prefer broken rice because it absorbs oil better than large grains. Lodging, tillering capacity, threshability, ease of hulling, swelling capacity and storability are other important criteria. Unfortunately, only few varieties combine all these characteristics and consequently women look first for varieties with the right duration, good yield, height and taste, and then as many additional characteristics as possible.

For a number of rice varieties grown in Tujereng, advantages and disadvantages are summarised in Table 5.3. Because of a general decrease in rainfall, farmers' variety choices have changed. Nowadays, the two most commonly grown upland varieties in Tujereng are *Kari Saba* and *Binta Sambou*, but before, when rainfall was higher, *Sefa Koyo* and *Sefa Fingo* were the common varieties. Both *Kari Saba* and *Binta Sambou* have a good yield, although differences with other varieties are very small (Appendix 4). *Kari Saba* is slightly earlier than *Binta Sambou*, but the taste is not so good and it is more difficult to hull. In 2000, after two years of good rainfall, some women were saying that they would grow more *Binta Sambou* than *Kari Saba*, but in 2002, a year with little rain, some women said it was better to opt for *Kari Saba*, because it matures slightly earlier, and is more drought tolerant.

Sefa Koyo nowadays is considered a late maturing variety, but is still cultivated because of its nice taste, big seeds, and easy hulling. *Sefa Fingo*, which is slightly later than *Sefa Koyo*, is still grown by a few women because of good taste, but the yield is not that high anymore because of the shortened growing season. According to women it does not do well in the lowlands. Apart from the two common varieties *Kari Saba* and *Binta Sambou* some farmers also grow other varieties, but that depends on individual choice (see Box 5.1 and Table 5.5). Also when *Sefa Koyo* and *Sefa Fingo* were the common varieties some women grew additional varieties.

Table 5.3: Characteristics of upland rice varieties grown in Tujereng (based on 2000-interviews and informal interviews).

variety	origin	time in Tujereng (# years)	use	duration [2]	positive traits	negative traits
Kari Saba	various places	+/- 30	common	3	yield, drought-tolerant	milling
Binta Sambou	Tujereng (field of *Kari Saba*)	10 –12	common	3	yield, taste, easy milling	slightly later than *Kari Saba*
Sefa Fingo	not known	many [1]	common in past	4	taste	late
Sefa Koyo	not known	many [1]	common in past	3.5	taste, big grain, easy milling	late
Sefa Kusee	*Sefa Fingo*?	many [1]		4		
Sefa Nunfingo	*Sefa Fingo*?	many [1]		4		
Hombo Wulengo	not known	many [1]		3	taste, big grain, easy milling	susceptible to termites
Kukur	not known	many [1]		3	big, soft grain, taste	low yield
Bendou	not known	many [1]		3.5	yield, swells	late
Moti	Yundum?	+/- 30		2.5		early
Mani Wulendingo	Yundum?	+/- 30		3	taste	early, shatters
Sonna Mano	Casamance	+/- 15		3		

[1] = at least 50 years, variety was already in the village when the oldest generation was born
[2] = from sowing to harvest, # months

Millet

Because of the decrease in rainfall in the 1970s, men had to change from late to early millet in many parts of The Gambia. For millet, like for rice, the most important criterion for variety choice is number of days to maturity. Contrary to rice, plant height is never mentioned for millet, nor is yield often mentioned. The reason yield is not often mentioned is that number of days to maturity, birds and blister beetles are the main factors determining yield. Hence, farmers have the perception that in some parts of the country early millet needs to be grown while in other parts late millet is the only choice.

Some farmers say that early millet with short spikes is better adapted to grow in infertile soil than early millet with long spikes. One farmer also said that the advantage of early millet is that it matures when farmers need food. In many areas women do not grow early maturing rice varieties anymore because of the risk of crop failure, and early millet can fill this gap. During the grain filling stage, millet can tolerate drought better than rice. Most early millet varieties do not have bristles, which makes harvesting and threshing easier.

Adaptation to less fertile soil is one of the reasons why in Fuladu farmers continue to grow late millet. They say early millet cannot grow well in poor soil. Another reason is that late millet fits their working schedule better. Some also say late millet only flowers when birds have left, attracted by other food sources.

In Western Division farmers grow another type of late millet (*sanyo*) which has many bristles to reduce bird damage. Particularly in Tujereng birds are abundant and Tujereng farmers say that if you dare to plant early millet, birds will eat everything and you will not harvest a single grain. The disadvantage of the bristles is that it makes harvesting and threshing more difficult. For *sanyo* another criteria is the colour of the seeds, which, according to farmers, is related to the taste and to the dishes that can be prepared. *Black sanyo* is more suitable for porridge (*monoo*) because it is said to have larger grains and to produce more powder. *White sanyo* is more suitable for *munko* (dough made of flour and water) because the flour from *white sanyo* makes the *munko* look very white and *serengo* (Jola dish for which coarse flour is needed) because *white sanyo* has smaller grains and can be pounded into small particles without producing too much powder. *Black sanyo* is the common variety in Kombo, while the only variety grown in Foni is *white sanyo*. Historically, Kombo was a Mandinka kingdom while Foni was only inhabited by Jola, so there seems to be an ethnic component in variety choice.

Varieties and cultivation practices

Rice

In Chapter 3 differences in cultivation practices between ecologies were described. Within the same ecology the same cultivation practices are used for most rice varieties, but there are a few exceptions. Normally, varieties are sown or planted in a pure stand. But if the maturity period of different varieties coincide, it is also possible to mix these varieties; especially if the quantity of seed one of those varieties is small. It also happens that if a woman wants to test a variety she sows it in a plot of another variety, either in a small area within the plot or scattered over the whole plot. For one variety, *Hombo Wulengo*, farmers say it needs to be sown in a mixed stand, otherwise termites will eat the stems of the rice plants. In 2001, YG sowed two varieties with a similar flowering period mixed, but found out that the ease of hulling was very different for the two varieties and decided that the next year she should sow the two varieties separately. However, a mixed stand is not always intentional. In some cases, a mixed stand results from a woman lacking seed and asking others for seed, which is not always pure. Another reason is that if, after sowing, germination is poor and all seed of a particular variety is finished a woman might opt to re-sow with a different variety. SB said that a particular variety, *Mani Mesengo*, needs to be sown at a lower density than other varieties. In general, women prefer to sow in a low density for plants to develop big panicles, which are easier to harvest than many small panicles.

Millet

Because in each ecology a different millet type (*sanyo*, *suno* or *majo*) is grown, differences in cultivation practices are related automatically to both ecological conditions and millet types. These differences have already been described in Chapter 3. Some farmers say particular varieties are better adapted to drought or poor soil. However, for each millet type, these farmers contradict each other by saying different varieties are more drought tolerant or better adapted to poor soils.

Box 5.1 Variety management by some rice farmers in Tujereng

PB (age: 60 years)
PB is member of the founding family of Tujereng. Her husband is sick and cannot work. They are supported by their son who is a civil servant. When she was young, her father was *alkalo* (village head). She has a great interest in rice, primarily based on curiosity, and thus a great knowledge of varieties. In 2000, she was growing 8 different upland varieties, just for comparison. In 2002, she changed from upland to lowland rice farming because she is getting older and wanted to reduce her workload. That year she did not grow the common varieties grown in the *faro*, but experimented with various other varieties.

FJ (age: 39 years)
She is also a member of the founding lineages of Tujereng. Because her husband does not have time to clear a field for her, she normally grows rice in second-year *tandako*, but in 2002, switched to lowland cultivation because she is the only adult woman in the compound and has to divide her time carefully between the work in the rice field and the work at home. In 2000, her field looked very colourful because another woman asked her to maintain some varieties for her. Normally, however, she does not have a big interest in variety choice and in 2002, grew the two most common varieties in the *faro*. She did say that she is interested in labour-saving technologies, such as threshing machines.

Sibi Sanneh (age: 50 years)
SS and her husband moved from Casamance about 25 year ago. Her husband is the leader of a group of Jola who settled in Tujereng recently. SS is the leader of a Jola *kafo*. She works the rice field together with her sister. Both are hardworking and knowledgeable rice farmers, although every year the time of sowing is uncertain because SS's husband is always late in clearing the bush for them. Every year they grow the two most common varieties and two less common varieties. One of these less common varieties is *Kukur* which she grows on a small area (less than 100m[2]) every year. The other less common variety she grows in varying quantities. Her husband said she should not grow this variety because of its lower yield, but SS likes its taste very much.

ST (age: 44 years)
ST and her husband settled about 15 years ago in Tujereng and originally come from Foni. They have relatives living in Janack. Her husband also earns money with tailoring. Although four adult women live in their compound, ST is the only woman who regularly works in the rice field. In 2000, she tried a variety and liked it very much. She was not able to sow this variety in 2001, however, because all the seed was eaten by the family. In 2001, she had a different variety for testing, which she also sowed in 2002. In 2002, she got a job in a primary school as a cook and could not work regularly in her field. That year, nobody else from her compound went to the rice field for bird scaring on a regular basis and consequently the harvest was a complete failure.

BG (age: 45 years)
About 10 years ago she settled in Tujereng. Her husband has another compound in Foni, where he stays most of the time. This means that BG has to run the compound by herself and has many responsibilities. To earn some extra money, she sells dried fish and condiments at the market. Every year, she grows the same two common varieties in the *tandako*. During the four year research period she did not test any variety in her field.

Tujereng: Other factors influencing rice variety choice over a 4 year period

In 1999, rains were extremely heavy; almost double the average annual rainfall. Part of the lowlands was completely flooded and the water table was too high for rice cultivation. In 2000, still some areas of the lowlands were inaccessible for rice growing. Hence, some women grew upland rice instead of lowland rice. In 2001, the water in the *faro* had reduced, and rice cultivation was possible again in all areas in 2001. Consequently, more women worked in the *faro* in 2001 and 2002 than in 2000 (Table 5.4). After the drought in 2002, some of the women growing rice in the *faro* stopped cultivation completely, and others changed to growing *tandako* rice.

Table 5.4 also shows a decrease in the number of women working in the uplands, which is explained by a number of factors. To a limited extent, the decrease was related to the improved accessibility of the *faro* in 2001 and, secondly, to the fact that some women got ill and could not cultivate rice. For the year 2002, drought partly explains the decrease compared to 2001, mostly affecting resource poor compounds. Another, important, factor in the decrease in upland rice farming was that women had difficulties in finding men to clear the bush for them. They said their husbands were getting too old to do the clearing, and that their sons did not want to do it. The sons had been to school and prefer would prefer office jobs to working in the fields. Further, it seems that personal conditions and interest lead to differences in variety choice and management (Box 5.1).

These paragraphs suggest that ecology choice, which influences variety choice, is a very dynamic process. However, this process is less dynamic in villages with one ecology (like Massembe) or with similar ecologies (like Janack).

Table 5.4: Dynamics in the number of women growing *tandako* and *faro* rice and the average number of varieties used by women in Tujereng from 2000 to 2003; N = 37 (based on annual interviews from 2000 to 2003).

year	total # women	women growing *tandako* rice			women growing *faro* rice		
	N	N	average # varieties / farmer	std. deviation	N	average # varieties / farmer	std. deviation
2000	37	34	3.2	1.61	11	1.7	0.79
2001	34	26	2.9	1.11	15	2.3	1.28
2002	31	16	2.6	0.62	16	2.2	1.11
2003	28	20	2.3	0.85	13	1.9	0.76

Table 5.4 shows a decrease in the average number of varieties, seemingly related to the decrease in upland farming. The data for *faro* rice also suggest a positive relation between number of farmers and the number of varieties grown. Table 5.5 suggests variety choice is not very dynamic. During the 4-year period monitored, the most common varieties were the upland varieties *Kari Saba* and *Binta Sambou* and the lowland varieties Bota Mano and Nyanya. However, if this study had been carried out early 1990s with the introduction of *Binta Sambou*, or early 1970s with the introduction of *Kari Saba*, Table 5.5 would have shown a dynamic picture of variety use. Thus, dynamic periods of variety choice alternate with more static periods over time.

Table 5.5: Dynamics in variety use of various *tandako* and *faro* varieties in Tujereng from 2000 to 2003; Number of respondents = 37 (based on annual interviews from 2000 to 2003).

tandako	2000	2001	2002	2003	*faro*	2000	2001	2002	2003
# farmers	34	26	16	20	# farmers	11	15	17	13
# varieties	18	15	10	11	# varieties	7	12	13	9
Bendou	3	3	1		*Balendingo Mano*		1	1	1
Bonti	1		3		*Bali Mano*			1	
Binta Sambou	31	25	16	20	*Bamba Mano*		1		
Casamance				1	*Binta Sambou*	1			
Chinese	1				*Bintou Mano*		1	1	
Foni Mano	2				*Bota Mano*	7	10	9	5
Hombo Wulengo	6	3	1		*CCF*	1			
Jokadou Mano	2	1			*Fatou Demba M.*				1
Kaca		1			*Hombo Wulengo* [2]		1	3	4
Kari Saba	28	20	10	15	*Kari Saba*	1			
Kukur	5	2		1	*Mani Koyo*	3	2	3	2
Mani Wulendingo	3	1	1	1	*Masarinding Mano*		4	12	9
Mani Mesengo	4	3			*Nyanya*	5	11	1	
Mani Mesengo II		1			*Nyaranding Mano*	1	1	1	
Muso Noringo	1				*Nyuko*		1	1	
Peking				1	*2 1/2 month*		1		
Sainey Kolly	1				*2 1/2 month II*				
Sefa Fingo	5	2	3	1	*Weserending Mano*		1	1	1
Sefa Nunfingo	1	2			*Yayang*			1	
Sefa Koyo	10	9	5	2					
Sonna Mano	3	1							
do not know name[1]	1	1	2	3	do not know name[1]			1	2

[1] For the category 'do not know name', the numbers indicate the number of varieties of which the name is not known of, not number of women.
[2] *Hombo Wulengo* grown in the *faro* is a different variety from the variety *Hombo Wulengo* grown in the *tandako*.

Variety replacement

With decrease in rainfall in the 1970s, many farmers replaced long duration varieties with shorter duration varieties, for both rice and millet. For rice, however, women constantly look for new and better varieties, even though they might already have varieties that suit their needs and preferences. It seems that only a few of the new rice varieties introduced into a village were adopted at any one time by many other farmers in the same village. The varieties *Kari Saba* and *Binta Sambou* were quickly adopted in Tujereng within a few years (Box 5.2 and 6.1). But other varieties were not as successful.

For millet, it seems that men are less active into looking for better varieties. They also argue that 'millet is millet'. In Tujereng most men say they grow the millet variety they got from their father. One farmer says about his variety choice:

> *I grow sanyo tima (sanyo with long bristles) that I inherited from my father. I also know nyo fingo (black millet) and nyokoyondingo (small white millet), which also have bristles, but I do not grow them, because I did not inherit them. Maybe if I would have inherited one of the other two varieties, I would only have grown that variety.*

It is thus clear that men do not bother much about variety choices. Many strangers settling in Kitti mentioned they had to replace their millet variety they brought with them with a local variety with more bristles. One farmer from Kitti mentioned that *sanyo* with white seed was slowly replacing the *sanyo* with the black seeds and predicted it would become the dominant type region-wide. Some farmers in Fuladu said that the short spiked *majo* is slowly becoming more popular. In Janack farmers said they discarded a variety with short bristles long time ago because children go to school and cannot do bird scaring anymore. So, male farmers also replace their variety when they come across better varieties, but this does not happen so often because fewer millet varieties circulate. Replacement is thus less frequent.

Box 5.2 The origin of *Binta Sambou*

Binta Sambou is now, together with *Kari Saba*, the most popular variety for the uplands in Tujereng. When I asked women in Tujereng about the origin of *Binta Sambou*, they all said that a woman named Binta Sambou picked some not-husked grains from a bag of imported rice and sowed it and multiplied it and gave it to others to grow, and that is why the variety is called *Binta Sambou*. When I asked Binta Sambou about the origin of the variety, she said she found an off-type plant in a field of *Likunda Mano*, nowadays called *Kari Saba*, that looked clearly different from *Kari Saba*. Binta said it ripened a little bit earlier than *Kari Saba*, it had taller stems (easier to harvest) and was tolerant of lodging. She said *Kari Saba* cannot resist strong winds (though measurement shows the two varieties have the same height and are equally prone to lodging).

Binta harvested the panicles of the plant separately. She sowed them the next year and harvested a big *bulu* (bundle of panicles held with one hand). The next year she sowed the whole *bulu* and she harvested 3 *bulubaa* (one *bulubaa* is a big bundle consisting of 8-10 *bulu*). That year she gave seed to her neighbours and relatives in the village. Other people who saw the rice variety in the fields were impressed by its performance and asked seed for it from people growing it. The year that Binta found the variety *Binta Sambou* in the field must have been around 1990. In 2000, almost everybody in Tujereng was growing big fields with *Binta Sambou* in the uplands. Musukebba Sambou, Binta's daughter-in-law who was born in Sifoe, also gave seed of *Binta Sambou* to her family in Sifoe, Gunjur, Kitty, Brufut and Tanji. From these places, it spread further over the region. Binta Sambou gave seed to her family in Essil in Casamance, where she originally comes from. In Casamance the variety is called *Secka Mano*, because Secka is the nickname of Binta Sambou.

Adoption of formal varieties by farmers

Rice

Regularly, surveys are conducted by NARI to evaluate the impact of formal rice varieties. In the irrigated areas almost all farmers grow formal varieties, while for other lowland areas, it is estimated that the varieties used are 40% formal varieties and 60% farmer varieties (Bittaye, personal communication). For the uplands the percentage of traditional varieties is likely to be higher, but it is unclear how much higher. Appendix 5, which is based on information from various NARI-researchers, lists formal rice varieties that are suitable for cultivation in the uplands and the upper stretches of the transitional zones. However, no records have been kept of which formal varieties were distributed by which NGO or government institution, in which area and in which years. Farmers themselves do not distinguish much between farmer and formal varieties. Hence, they are not a good information source on the use of formal varieties. In some cases, but not all, morphology and/or names can be used as indicators of whether particular varieties are farmer or formal varieties. Formal varieties are often short in height, have a whitish or reddish husk colour and white seed colour. Farmer varieties are tall, often have a red or brown seed colour and some have awns or an unusual husk colour. The names farmers give to formal varieties are sometimes derivatives of the actual names of formal varieties, or indicate origin, like the name *Chinese Mano*. In some cases women mentioned that some varieties were in the village with their mothers (about 50-60 years ago), which means it is unlikely that such varieties are formal varieties.

When combining the information from farmers and the formal sector with the comparisons of varieties in field trials an almost complete picture emerges for upland rice varieties grown in Tujereng, Kitti, Faraba and Janack (see also Chapter 10). Based on this information, almost all rice varieties grown in Tujereng are farmer varieties, while in the other villages, Faraba, Kitti, and Janack, formal varieties are common. The presence of some formal varieties is linked to certain events. In Janack rice farming was re-introduced in 1994 by the NGO SJFF (Sint Joseph Family Farm) which brought short duration, mostly formal, varieties (*Peking, Rasi, Parasana* and *WAB 56-50*) and one farmer variety called *Kumoi* (also called *Borro borro*). In Faraba, after the construction of dikes in 1996, SWMD (the Soil and Water Management Department) gave farmers formal varieties, which fit best the new growth conditions created with the construction of the dikes. Also in Kitti, NGOs and extension services distributed formal varieties on a large scale to farmers. In Tujereng it happened twice that an NGO and/or extension officers brought rice varieties. In the 1960s, a white man came to Tujereng to sell rice seed and offered the same varieties farmers that were growing in those days, but out of curiosity many farmers bought his seed. The second time was in 1982, when an extension officer brought a 3-month variety, *Barafita koyo*. All of these materials were, in fact, farmer varieties. In 1998, NARI set up a Participatory Varietal Selection trial in Tujereng with formal varieties. All but one participating farmers received no seed from the trial.

So it seems logical the reason only a few farmers in Tujereng grow formal varieties is that farmers have not been exposed to them. However, when showing some formal varieties to Tujereng farmers they explained they had tried them, but some were too early, others too short, or both. Furthermore, because farmers get seed when travelling to distant places, it would be strange if they had no exposure to formal varieties. The most likely explanation only very few Tujereng farmers are growing formal varieties is that there is still enough rainfall for the farmer varieties to mature. During the drought of 2002, one of the farmers said that if rains continue to be like this in future, she will have to change to short duration varieties. In 2003, a few farmers grew short duration formal varieties and many farmers asked for seed of these short duration varieties. However, some of these varieties performed poorly as they were adapted to lowland conditions. Television played an important role in the increased interest in formal varieties as farmers could see the good performance of formal varieties (including Nericas) in Jambanjeli, a neighbouring village. What farmers did not fully realise that much, however, was that in Jambanjeli these formal varieties (including Nericas[9]) were planted under lowland conditions.

Millet

In 1972, ICRISAT stated that the improvement of late millet would receive major attention, since the average yield of late millet for Africa is only 733 kg/ha while 3-4 tons/ha are obtained in North America and Oceania (Haswell, 1991). Although a few late millet varieties have been developed for Indian agriculture, no suitable late millet varieties were developed adapted to African agro-environmental conditions. In West Africa ICRISAT focuses on early or medium duration millet varieties. No work has been done on the improvement of late millet in The Gambia because of the decrease in rainfall, and so discussing formal varieties in this thesis almost automatically means discussing formal rice varieties. Because of the shortening of the rainy season NARI works on early millet only and some formal varieties of early millet have been released that can compete with farmer varieties in yield, but are not superior. Apparently, this is a common phenomenon in the whole of West Africa (Matlon, 1985, in Niangado, 1999).

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[9] The Nerica varieties were actually developed for upland cultivation but Jambanjeli farmers found out that they perform much better under lowland conditions.

African versus Asian rice

There are various explanations about when and how *Oryza sativa* was introduced into West Africa (by Arab traders via the Sahara desert or overseas with Portuguese traders) but it is clear that the first rice farmers in The Gambia grew was *Oryza glaberrima*, which farmers nowadays call *Mani ba* in Mandinka. *Mani ba* means 'old rice' and '*ba*' is also used to indicate respect. Nowadays, only few farmers grow it. In Tujereng the younger women do not know much about *Mani ba*, but some older women know it is the oldest rice, older than all other rice varieties, and that it originates in the *faro* (lowland). The explanation is as follows:

> *When there was a drought in the faro, all rice died and people did not have any seed. The next year Mani ba was the only rice to germinate in the field. So, people harvested the Mani ba and used that as seed again the next year, and so on. That is why Mani ba is the oldest rice. This happened a very long time ago.*

The older women say their mothers used to sow *Mani ba*. The main reason to grow *Mani ba* was that it flowers early and was the first rice to be harvested. In most cases they sow it mixed in fields of *O. sativa*, because the *Mani ba* does not yield much and it would be a waste of land to sow *Mani ba* in a pure stand. Some women, however, say 'it is a saying that *Mani ba* does not yield much'. SB says that in the past she used to grow it in pure stand and that it yielded well. It seems a common practice in many West African countries to sow *O. glaberrima* and *O. sativa* mixed, often in equal ratios (Jusu, 1999; Oka *et al.*, 1978). In this study, the interviewed farmers who mixed the seed said that at maximum 10% of the seed should be *Mani ba*. If the percentage of *Mani ba* is much higher, it kills (out-compete) the other rice because *Mani ba* tillers abundantly and flowers earlier. In Sierra Leone farmers mix *O. glaberrima* and *O. sativa* varieties that flower at the same time (Jusu, 1999), which might explain why in Sierra Leone farmers use mixtures of equal ratios.

PB says that in the past women preferred pounding *Mani ba* instead of findo (*Digitaris exilis*), which is more difficult to pound than *Mani ba*. When men stopped growing findo (because of lack of labour, when children started going to school), there was also less of a need to grow *Mani ba*. This development started in the late 1950s[10]. In those days the bad smell associated with rice sold in shops also became less, which likely coincided with the sharp increase in rice imports around 1970, which was another reason for women to stop growing *Mani ba*. Although pounding *Mani ba* is easier than findo, pounding *Mani ba* is still very difficult compared to *O. sativa*. Around 1970, the first early maturing *O. sativa* variety, a farmer variety named *Kari Saba*, was introduced in Tujereng. The introduction of *Kari Saba* was another reason for women to stop cultivating *Mani ba*, and it is likely that with the introduction of *Kari Saba*, the cultivation of *Mani ba* saw a sharp decline.

In the past, the main advantage of *Mani ba* was its earliness. Its disadvantages were low yield, difficult pounding and many small panicles, which makes panicle harvesting difficult. Difficult pounding seems to be typical of *O. glaberrima* (Richards, 1996). Under normal conditions however, like in 2001, it does not seem to perform worse than *O. sativa*. A few women mentioned that the low yield of *Mani ba* is possibly rather belief than fact. Another disadvantage is that its taste is only nice for certain dishes (like *munkoo* and *satoo*), but is less suitable for the main dish, because of its lesser taste and because it does not swell that much. The last disadvantage of *Mani ba*, according to some farmers, is that *Mani ba* needs more rain to grow well, although it ripens as early as *O. sativa* varieties. The 2002-season showed that during the grain filling stage *O. glaberrima* does not tolerate drought at all and is more drought-

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[10] According to Sanneh (personal communication) farmers started replacing *O. glaberrima* in the 1950s.

susceptible than *O. sativa*. Whereas in this study *O. glaberrima* appeared to be clearly drought susceptible during the grain-filling stage, in the literature *O. glaberrima* is often cited as more drought resistant than *O. sativa* (Oka *et al.*, 1978; Nyanteng *et al.*, 1986).

Women say they only mix *Mani ba* in the seed which is meant for *tandako*, but not for *faro*. *Mani ba* originates in the *faro* and therefore it is not necessary to mix it in the seed for the *faro*: There is always some *Mani ba* seed in the soil of lowland areas, whereas there is not in the upland areas. Nowadays, *O. glaberrima* is mostly present as a weed in farmers' fields, particularly in the lowlands, including the transitional zones. In the lowland areas of Kitti and Faraba *Mani ba* is much more common than in the *tandako* of Tujereng and farmers rather seem to dislike it in their fields. In Kitti and Faraba women call *O. glaberrima* '*Lola*', which means 'standing straight up', because it panicle stands straight up, unlike the bending panicle of *O. sativa*. *Lola* sounds less respectful than *Mani ba*.

Many of the older women of Tujereng, however, say they are happy if they see it in their *tandako*, and some say they mix few panicles of *Mani ba* in the seed, because it is the oldest rice; it is a tradition. It is also a kind of security to have it in the field so that it will not get lost. Some older women also said that if you see *Mani ba* in your field, you know you will have a good harvest, it will bring you luck. In Sierra Leone some farmers believe it is good to have *O. glaberrima* as an off-type in the field because it acts as protection against witches (Longley, 1999). This might be just as well being told as a justification because it is very difficult to fully remove *O. glaberrima* from the seed stock.

Although it has a distinct panicle structure, women still fail to separate out *Mani ba* when harvesting, because of time constraints and because the seed size and shape and husk colour are very similar to Asian rice varieties. Also, because of farmers' seed selection procedures (mostly removing off-types from big tight bundles), many off-types, including *Mani ba*, remain in the seed after harvesting (see Chapter 4). Possibly, the harvesting and seed selection methods exert a strong selection against shattering in *O. glaberrima*. Farmers from Tujereng complained that it is difficult to thresh and to pound, whereas much literature (Linares, 2002; NRC, 1996) states that one of the main disadvantages of *O. glaberrima* is that it is prone to shattering. However, careful scrutiny shows that non-shattering types undoubtedly can be found (NRC, 2002). This suggests that information about the traits and the variation found in *O. glaberrima* is incomplete.

All varieties distributed by NARI and NGOs are *O. sativa* varieties and it is possible that the focus of NARI and NGOs on *O. sativa* varieties contributed to the disappearance of *O. glaberrima* in farmers' fields in The Gambia.

5.4 Discussion

Key issues relating to variety management dealt with in this chapter are the number of varieties used, variety choice and preferences, variety replacement, use of formal varieties and of *O. glaberrima*.

Why do farmers use a range of varieties?

In this study 112 rice varieties and 6 millet varieties (4 late and 2 early millet varieties) were identified. The large number of rice varieties is in agreement with other studies on rice in other countries (Richards, 1986; Dennis, 1988; Lambert, 1985). NARI researchers indicated that countrywide 6 to 7 early millet varieties are used, which means that in the whole of The Gambia about 11 varieties of pearl millet are cultivated. In Niger it was found that 33 varieties were grown in 58 villages (Ndjeunga, 2002). In a study in central Burkina Faso 90 landraces of pearl millet were collected (Wilson *et al.*, 1990). So, whereas the number of rice varieties in this case study is similar to other studies the number of millet varieties is less compared to other studies.

At the farmer level there are also differences with other studies for millet but not for rice. In this study the average number of rice varieties was found to be about 3 per farmer, comparable with averages found for rice in Sierra Leone (Richards, 2005) and Thailand (Dennis, 1988) and somewhat lower than the average of 3 to 5 found in Nepal (Bhuktan *et al.*, 1999). For millet, Gambian farmers only use one variety of millet, while in countries like Nigeria (Busso *et al.*, 2000), Burkina Faso and Niger (Berthaud *et al.*, 2001) farmers generally cultivate 3 varieties of millet adjacently in the same field. For maize in Mexico (Louette *et al.*, 1997), farmers also use 2-3 varieties per season. So, the number of rice varieties used per farmer in The Gambia compares more to millet in Burkina Faso and Niger or maize in Mexico. For crops like potato in Peru (Zimmerer, 1998; Brush, 1995), beans in Rwanda (Sperling *et al.*, 1993) and sorghum in Northern Ethiopia (Teshome *et al.*, 1999; Seboka, 2005), farmers use far larger numbers of varieties, variety averages ranging from 9.5 to 21 per farmer. In Eastern Ethiopia and Southwest Zimbabwe, however, farmers often grow, respectively, 'only' 2 and 3 to 4 sorghum varieties (McGuire, 2005; Van Oosterhout, 1996).

When only comparing rice and millet in The Gambia, breeding system seems to explain the differences in the number of varieties that exist. However, from the paragraph above also follows that a set of factors is needed to explain the differences in variety use in the various case studies. Other factors are ecological complexity, farmer crop portfolio, use purposes, ease of reproduction and labour availability. Because in the Gambian case study villages different social groups work in the same or different rice ecologies, it is difficult to draw any conclusions on the effects of socio-economic and cultural factors on variety management. Below, these factors are compared with information available from other case studies. A summary of this comparison is shown in Table 5.6.

<u>Ecological conditions</u>

Countrywide, only 2, or at most 3, different ecologies can be recognised for millet, whereas for rice within one village 2 or 3 ecologies can be found, and these often also differ between villages. For rice, ecological conditions are far more complex than for millet, which partly explains the large number of rice varieties that exist. A similar logic was also put forward by Richards in the case of rice in Sierra Leone (1986). In Mexico and Ethiopia where the ecological environment is also complex, farmers also match varieties to agro-ecological conditions (Louette *et al.*, 1997; Seboka, 2005). However, in the Peruvian Andes, where potatoes are the main staple food, farmers do not match varieties to specific ecological conditions, although they use a wide range of varieties (Zimmerer, 1998; Brush, 1995). Consequently, the agronomic advantage in the large diversity in Peruvian potato is difficult to ascertain (Brush, 1995).

<u>Farmer crop portfolio</u>

Diversity within crops is also linked with the number of crops cultivated by farmers. In Nigeria (Busso *et al.*, 2000), Burkina Faso and Niger (Berthaud *et al.*, 2001) farmers generally cultivate 3 varieties of millet which is the most important crop in those countries. The main reason to grow 3 varieties simultaneously is yield security in a drought prone environment (Busso *et al.*, 2000). In the Gambia climatic conditions are somewhat more reliable and farmers grow a range of crops (see Chapter 2). These two factors might explain why Gambian farmers grow only one variety of millet. Instead of diversifying within a crop, Gambian farmers diversify by growing several crops during the rainy season. This also, partly, explains the small number of sorghum varieties grown by Gambian farmers compared to the large numbers grown in Ethiopia. The same explanation might be applicable to the low number of sorghum varieties in Southwest Zimbabwe. As is shown in Chapter 2, Gambian women grow few crops besides rice during the rainy season but diversify by growing a range of rice varieties, while during the dry season they diversify by growing a range of vegetable crops in their gardens.

Use purposes

This study shows that women use more selection criteria for rice varieties than men use for millet varieties. This can partly be explained by the fact that many more varieties and ecologies exist for rice than for millet, but also by the fact that women are not only the cultivators but also the processors (threshing, milling, cooking) of rice. Other criteria common in other study areas, like market value (Richards, 1986; Teshome *et al.*, 1999; Bellon and Taylor, 1993), suitability for beverages (Teshome *et al.*, 1999) or suitability for fodder (Louette *et al.*, 1997; Bhuktan *et al.*, 1999; Weltzien *et al.*, 1996) or fuel (Bhuktan *et al.*, 1999) were not mentioned by Gambian farmers. Because both rice and millet are subsistence crops in The Gambia, market value is not important. The reason farmers do not mention fodder quality of millet is probably because groundnut stover is used as fodder instead. Farmers also say that groundnut stover is a better fodder than millet leaves and stalks. The reason that suitability for beverages is not mentioned is that nowadays most Gambians are Muslims. In the past, millet stalks were considered a farm product that could be used for fencing (Gamble, 1955), but nowadays people rather use brick walls and barbed wire for fencing.

Variety choice can be considered a process in which farmers match bundles of traits with agronomic conditions, consumption preferences and marketing requirements (Bellon and Smale, 1998). Teshome *et al.* (1999) also found a positive correlation between the number of cultivated sorghum varieties and the number of selection criteria used by farmers. So, compared to farmers in other regions of the world, Gambian farmers need a relatively small number of varieties because they also have fewer variety selection criteria. In the case of sorghum, Gambian farmers mention the same limited criteria as for millet, which in turn implies a lesser need for a wide range of sorghum varieties. Farmers in Mexico use many maize varieties because none of the varieties meet all the selection criteria (Brush, 1995; Rice *et al.*, 1998). This case study on late millet also shows, however, that a particular selection criterion, bristles for bird resistance, also reduces, according to farmers, the choice of possible varieties. In the case of potatoes in Peru the high variety number is not explained by a large number of selection criteria (Zimmerer, 1998). Instead it might be related to ease of reproduction (because it is vegetatively propagated) and a coping strategy with extreme and unpredictable conditions. So, in general it can be said that the more criteria, the more varieties farmers need, but there are exceptions to this rule.

Cultural purposes

Although millet and rice are culturally important in The Gambia (see Chapter 2), there are not any varieties that are used for particular cultural purposes. Before Gambians converted to Islam, cultural purposes might have been more important. Older Gambian farmers believe the presence of *O. glaberrima* in their fields brings luck and therefore needs to be preserved, but the younger generation considers it mostly a weed. In Southern Casamance where Jola have not converted to Islam, particular rice varieties are used for traditional religious rituals (Linares, 1992). In Sierra Leone the Susu relate the presence of *O. glaberrima* in their rice fields to various beliefs about both ill and good luck (Longley, 1999). Among the Mende in Sierra Leone red rice (soaked in palm oil) is an important feature of sacrifices to the ancestors (Richards, 1996b). Rice varieties are also valued for their own sake, e.g. as curiosities

(Richards, 1996a). In the case of potatoes in the Peruvian Andes varietal diversity is also used for cultural and social purposes, such as gift giving to strengthen social ties (Brush, 1992). Hence, cultural purposes contribute to and maintain varietal diversity. Cultural importance also determines how carefully people look at plants and animals and how much diversity they recognise (Boster, 1985). Related to this is the history of a crop in a particular farming system and the familiarity of farmers with that crop. In Zululand in South Africa, where potato is a relatively new crop, farmers usually only grow one potato variety and do not distinguish between potato varieties, whereas they do for sweet potato varieties, with which they have greater familiarity and for which they have several uses (Nuijten, unpublished).

Ease of reproduction

Another factor related to variety number is ease of reproduction. Bray (1986) explains that rice has a much higher multiplication rate per seed than cereals like wheat or barley. Crops like sorghum, maize and millet also have the advantage of a high seed number per inflorescence and low plant densities, which means a farmer only needs to harvest a few panicles, cobs or spikes to obtain sufficient quantities of seed. This, possibly, is also a factor in explaining the high number of sorghum varieties existing in Ethiopia or potato varieties in Peru.

Table 5.6: Summary of the number of varieties per farmer for various crops and countries and the main factors explaining these differences.

crop / country	# varieties / farmer	% cross-pollination	# main crops	eco diversity	eco extremity	use purposes	ease of reproduction
rice / Gambia	3	0-1%	1	low-middle	low-middle	few	high
rice / Thailand	3	0-1%	1	low-middle	low-middle	few	high
beans / Rwanda	many	2-3%	?	middle	middle	middle	medium
millet / Gambia	1	70-80%	2-3	low	low	few	high
millet / Nigeria	2-3	70-80%	1	low	high	few	high
maize / Mexico	2-3	80%	1	high	low-middle	middle	high
sorghum / Ethiopia	2 - many	5-10%	1	high	middle	many	very high
potato / Peru	many	vegetatively propagated	1	high	high	middle	high

Labour organisation

Labour organisation also plays a role in variety management. Some women said that in the old days when more women went to the rice fields, it was possible to grow bigger areas and to use more varieties, including African rice. In Janack some men also mentioned that in the past, when boys went to the field instead of to school, they grew two varieties of millet instead of one. In southern Peru a similar pattern is apparent where farmers, because of labour shortages, grow fewer potato and maize varieties than before (Zimmerer, 1991).

Other factors

The data in this study suggest that farmers who need to borrow seed often use more varieties, possibly as a coping strategy. It is often suggested that wealthier farmers use more varieties (Dennis, 1988), but in this study no information was found to confirm this hypothesis. Likely, this is because Gambian and Thai rice farming systems are very different. To better understand the impact of various socio-economic factors on farmer variety management farmers' styles of farming as outlined by Van der Ploeg (1994) might be useful. As argued by Prain (1994), personal interest also plays a role in variety management. As personal interest, to some extent, influences farmers' styles of farming, the role of personal interest can be better explained by defining farmers' styles of variety management. In this study no data were collected to substantiate these hypotheses, but it might be useful to pursue this line of thought.

Dynamics in variety choice and preferences

Above it is outlined that many factors influence the number of varieties used. Which varieties are chosen not only depends on which varieties fit a farming system best, but also on the uses of the different crops in a farming system. Variety preferences are the result of a process in which a farming system adapts to its environment. Which traits are desired and unwanted is not only related to environmental factors, but also to socio-economic factors. The decrease in rainfall in the early 1970s had a clear impact on variety choice, particularly for rice. Because of schooling, less labour is available at compound level for rice pounding and bird scaring in millet fields. Farmers explained that, 40 years ago, pounding *O. glaberrima* was not considered difficult, because findo was even more difficult to pound whereas, nowadays, when most farmers do not grow findo anymore, *O. glaberrima* is considered very difficult to pound. This shows that concepts of desired and unwanted traits are related to the traits and diversity of available varieties and thus that these concepts are flexible. Thus, variety preferences of farmers are defined by socio-economic and agro-ecological conditions and the range of accessible varieties and crops, and the diversity they represent. This probably also explains differences in outcomes on studies on the importance of yield and taste to farmers. In farming systems where crop varieties do not differ in taste, taste is likely a less important criterion than in farming systems where crop varieties greatly differ in taste.

Furthermore, variety choice and preference are not the same. Farmers need to choose varieties that do well in the field, even though those varieties do not meet all farmers' preferences. In one way, men regard bristles as an unwanted morphologic trait of millet varieties, because it makes working in a millet field more difficult, but they also consider it necessary to ward off birds. Likewise, women prefer tall rice varieties, but if only short varieties are available with the right duration, they will work with those short varieties. Women also say they like varieties with big grains, but particularly in the uplands the best performing varieties (both farmer and formal) have small grains.

Variety choice and social dynamics

In the village of Tujereng most women know which are the common varieties in the uplands and, although to a lesser extent, the lowlands, where two varieties are more common than the other varieties. There is also a seemingly purely agricultural reason for this: The two common varieties in the uplands ripen at the same time, one slightly earlier than the other, and the other tastier and easier to pound. Some women also mentioned that it would be possible to grow earlier maturing varieties, if only everybody would grow those earlier maturing varieties. The lowlands show the same picture: The two common varieties in the lowland are both late maturing, so that bird scaring is not necessary at maturity stage. This indicates that there is also a social component in variety choice. It also means that the success of better varieties for which the farming system at village level needs to be changed (bird scaring for early varieties) depends on simultaneous and massive adoption by farmers.

The same mechanism is apparent in millet variety choice. Often, men said that it is possible to grow early millet in Tujereng if only everybody would grow early millet at the same time, spreading bird damage over many fields. In that way each farmer loses some of his early millet crop but no farmer would have a total failure. Now that fewer farmers are growing late millet, the severity of bird damage has increased dramatically even though late millet has bristles. Also, farmers said bird damage would not happen if only more farmers grew late millet. Because sorghum is less affected by birds than millet, some men now have started growing sorghum instead of millet, even though sorghum is not as palatable. This shows that there is also a social aspect to crop choice, similar to variety choice.

Dynamics in variety replacement

It is often argued that farmers regularly incorporate and discard varieties (Richards, 1986; Dennis, 1988; Bellon, 1996; McGuire, 2005). But it might be possible that such studies were conducted during more dynamic periods, and that if they were conducted at different periods of time, less dynamic picture would have emerged. During the period of this study (2000 to 2003), farmers did not change varieties much, but in, respectively, early 1990s and 1970s the spread of varieties like *Binta Sambou* and *Kari Saba* was very fast in the village of Tujereng. This implies that dynamic periods of variety change alternate with periods of stabilisation over time. A study on maize in Mexico shows that periods of variety replacement often coincide with major junctures in farmers' lives (Rice *et al.*, 1998). The same might apply to Thailand where some villages show very dynamic variety management, while other villages show more static variety management during the same period (see Dennis, 1988).

The information in this study shows a more dynamic variety management for rice than for millet over the past 50 years. When talking to male and female farmers, it appears that women are constantly looking for new and better rice varieties, even if they have varieties that suit their preferences. For millet, however, it is quite rare to hear men talking about testing different varieties and often they say: 'millet is millet' or 'all millet is the same'. From this, it might be concluded that women are more interested in variety management than men are. However, men do not replace varieties of millet often because fewer varieties circulate. Replacement of millet varieties is thus much less frequent and happens more on an intergenerational scale. After the reduction in rainfall in the 1970s, rainfall was too little for the cultivation of late millet in the northern part of The Gambia and farmers changed to early millet during the 1980s. To what extent this is related to gender will be discussed in Chapter 9.

Formal seed supply and formal varieties

It is often said that in the past the formal sector developed and disseminated varieties that do not match the needs of all farmers (Jusu, 1999; Sperling *et al.*, 1993; Simmonds and Talbot, 1992, Hardon and de Boef, 1993). This is also true for rice varieties introduced in The Gambia for upland cultivation from the 1960s to the 1980s. None of these varieties were specifically developed for upland rice cultivation but for use in irrigated lowlands. It is often said that Gambian farmers need tall rice varieties, but 20 to 30 years after their introduction short formal varieties like Peking and Se 302G can still be found in farmers' fields. This confirms that farmers' variety criteria are flexible. Research reports also offer a second explanation why formal varieties are not often adopted by farmers, not often put in writing. In research trials, potential varieties were often identified, but were never tested in farmers' fields, or if they were tested and proved their potential in farmers' fields, were never multiplied because of discontinuity of funding. This is not only a typical Gambian problem, but common in the whole of West Africa and beyond (Richards, 1985; Ndjeunga, 2002).

Since 1975, the rice world price has gradually decreased (see Chapter 2), which means that rice sold in shops is not very expensive. If rice in shops was more expensive, Gambian farmers would emphasise more on rice farming, and possibly also use fertiliser to increase production. This in turn would promote adoption of formal varieties, because, if fertiliser is used, formal varieties give higher yields than farmer varieties. Nowadays, however, Gambians consider the use of fertiliser on rice as too expensive and risky. Richards (1995) points out that 'foreign' technologies can be very successful if they are compatible with pre-existing patterns of thought, social relations, and ecological patterns, and if farmers are allowed time to incorporate these new technologies in their farming system, which might take several years. In a case study on the distribution of formal bean varieties in Rwanda, Sperling and Loevinsohn (1993) also argue that potentially successful varieties might get lost due to accidents before they are widely distributed among farmers and have found their niche. To avoid such failures, seed should be distributed among a wide range of farmers and over a longer period of time, for example through local markets and stores (Sperling and Loevinsohn, 1993).

5.5 Conclusions

The following conclusions can be drawn from the information in this chapter:

- More rice varieties exist than millet varieties.
- Women use more rice varieties than men use millet varieties.
- The main factors to explain these differences are, apart from breeding system, ecological diversity, ecological extremity, farmers' crop portfolio, use purposes, ease of reproduction and labour organisation.
- Farmers' explanations of why there are more rice varieties than millet varieties are related to differences in crop phenology and characteristics, and to cultivation systems.
- Variety replacement is determined by changing ecological and socio-economic factors and the availability of varieties.
- Variety choice and preference are not the same and both can change over time, depending on the range of available varieties and the diversity they represent.
- Successful variety adoption is determined at two levels: the farmer and the village.
- Whether a variety can be adopted by individual farmers or whether it needs to be adopted at village level depends on the type of traits of that variety (e.g. taste versus earliness).
- Farmers do not continuously replace their varieties, but dynamic periods of replacement alternate with periods of stabilisation.
- Farmers do not distinguish between farmer and formal varieties.
- Most formal rice varieties used by farmers in the uplands are developed for irrigated cultivation.
- No formal varieties of late millet are developed suitable for Gambian conditions.
- With the decrease in rainfall in the 1970s and the availability of short duration *O. sativa* varieties, *O. glaberrima* lost its main advantage (earliness) and, nowadays, is not commonly cultivated.

6 Seed flows and variety naming

6.1 Introduction

Genes flow via seed and pollen. These two processes are described separately in this chapter and the next. Chapter 4 showed that seed selection does not shape varieties and diversity much. This is in line with McGuire (2005) who argues that the emphasis in research on seed selection is misplaced and that the high turnover of seed lots and seed exchange may be more important for the overall functioning of the informal seed system. In an informal system seed is exchanged through family ties, friendships, trade and labour relations. Seed is exchanged within and between villages, sometimes over large distances. Distances over 1000 km are reported in Ethiopia (McGuire, 2005). To understand such systems, it is important to understand the social networks through which seeds flow (Seboka and Deressa, 2000). According to McGuire (2005), it is the wealthier farmers who seek out and screen new varieties, playing an important role in the system. It is also stated that seed suppliers are often the better-resourced households in farming communities (Wright *et al.*, 1994; Dennis, 1988). Richards (1990) considers it a flexible system in which the rules can change depending on the circumstances. The system also has its disadvantages. Not automatically everyone who asks for seed obtains it (Sperling and Loevinsohn, 1993). This may be explained by the fact that no fixed rules exist for seed exchange between farmers, and transactions are influenced by the relationships between farmers, their social positions and the degree of confidence between them (Seboka and Deressa, 2000; Badstue *et al.*, 2002).

Apart from social status and networks, a consistent nomenclature is very important to obtain or exchange the right variety. In Ethiopia, for example, where farmers frequently exchange seed between villages along the same road, variety naming is very consistent (Teshome *et al.*, 1997; Tunstall *et al.*, 2001). In Lao PDR the same name can refer to different varieties, particularly when different regions are compared (Appo Rao *et al.*, 2002a). In the Peruvian upper Amazon it was found that 50% of the names given to cassava varieties were unique to a particular family and that, as a result, the same variety was often given different names by different families (Salick *et al.*, 1997). If farmers name varieties consistently, this could be used to estimate genetic diversity (Quiros *et al.*, 1990). It would also facilitate understanding the course and spread of varieties. In the early stages of the fieldwork in The Gambia it appeared that variety naming was not consistent between villages, and in particular cases not even within villages. This was confirmed by various NARI researchers, who added that this also complicates research on the farmers' variety portfolios and the adoption rates of formal varieties.

Since millet is an outbreeder grown by men and rice an inbreeder grown by women, one of the main research questions treated in this chapter is whether and how breeding system and gender influence seed flow. A second research question is whether and how breeding system and gender influence variety naming. The first part of this chapter describes seed and variety flows. Here, seed flow refers to the replacement of lost seed of cultivated varieties, whereas variety flow refers to the acquisition of 'new' varieties. The second part of this chapter describes variety naming. Variety naming gives information on the flow of varieties. Varieties are named after the village or farmer from whom they were obtained. Further, variety naming indicates how common a variety is within a village, the speed of dispersal within villages and the period of time a variety has been used.

6.2 Materials and methods

Using semi-structured interviews conducted in Tujereng, Kitti, Faraba and Janack in 2000, information was obtained on the places of origin and the naming of rice and millet varieties. The questionnaire conducted in 2002 gave data on seed loss, seed distribution, variety sources and variety names. Together with this survey as many rice samples as possible were collected. Since variety names are not always used in a consistent way, the collected samples were meant to facilitate understanding about how many and which varieties were grown in which villages. In one village, Damphakunda, many women suffered bad harvests and could give very few samples. Consequently, this village was discarded from the analysis. Other interviewees did not have the key of the rice store, stored their seed in places difficult to reach, or were reluctant to give seed.

For rice, 10 panicles are a sufficient sample for comparison. First, the samples of Tujereng, Kitti, Faraba and Janack were compared and grouped visually. Those samples of which similarity with other samples was unclear were sown in two single-replication trials (one for short duration varieties and one for long duration varieties) to observe differences in plant height, time of flowering, basal leaf colour, tillering habit and leaf angle. Due to time constraint, comparison of the samples from the other villages was completed after the rainy season of 2002. For comparison of millet samples, samples should consist of at least 50 inflorescences, because of the greater variability within varieties. However, because millet spikes are rather large, a sample of 50 millet spikes would be too large a sample to ask farmers to provide. The millet samples obtained from farmers often consisted of threshed seed. Consequently, for millet, variety sampling and analysis was not done as extensively as for rice.

6.3 Seed and variety flows

Seed loss

Seed flow (the replacement of seed) is directly related to seed loss. In this section will be discussed how and how often farmers lose their seed. The total percentages of women who need to borrow rice seed and men who need to borrow millet seed do not differ much (Table 6.1). However, there is a big difference between women transplanting and broadcasting rice. Bad harvest is the main reason farmers borrow seed for both rice and millet. Women who transplant rice experience bad harvests less often, because of more reliable water supply. For broadcast rice, drought is the main problem. Millet suffers from pests like striga, blister beetles and birds. Because of active bird scaring by women, birds rarely cause a bad harvest in rice. In millet, however, men do not scare birds, and birds have free access. For both millet and rice, particularly the non-flooded rice, cattle can also cause bad harvests. Monkeys, grass cutters, and rabbits cause problems in rice, but rarely bad harvests.

Often, seed for sowing and consumption grain are stored in the same store, and if the person responsible for the store is away, it may happen that other family members use the seed for cooking. BS explained that because *Hombo Wulengo* is easy to pound, the children pounded all, including the seed. For this reason, often only one or two older people in the compound have a key to the store. Although in many stores you can find insect infestation, storage pests rarely lead to a complete loss of sowing seed.

Illness is another factor that can lead to loss of sowing seed, particularly for women, because they often work on their own (see Chapter 2), unlike the men who work in bigger groups. If a woman gets ill, or if something important happens unforeseen, nobody will attend to her rice field often resulting in a crop failure.

Table 6.1: Percentages of farmers who needed to borrow rice and millet seed in the past 5 years (data from 2002-questionnaire).

ecology	respondents (N)	farmers who borrowed seed (%)	*reasons to borrow seed* bad harvest	seed eaten	storage pest	not enough stored	illness
rice							
upland	21	33	29	0	0	0	5
faro, sown	35	43	34	6	3	0	0
faro, sown and planted	26	42	19	8	4	8	4
faro, planted	27	7	7	0	0	0	0
faro, mangrove	19	11	0	5	0	5	0
rice, average	128	29	20	4	2	2	2
millet							
sanyo	89	28	17	5	3	3	0
majo	20	15	10	0	0	5	0
suno	25	20	12	0	8	0	0
millet, average	134	25	15	3	4	3	0

If you ask people whether they have lost their sowing seed, people, particularly men, are often somewhat offended. Some men tell you they have not lost their sowing seed since they got it from their father, 40-50 years ago. ST said: 'I never lacked seed; seed is one of the first things to think about. Besides, many people come to me for sowing seed'. This indicates people take a certain pride in not losing their seed. Possibly, men as patrons take more pride in having and being able to supply seed. For millet, another factor plays a role: When millet is threshed, it is difficult to distinguish early from late millet. For rice, it is still possible to distinguish different varieties when they are threshed, although there is some confusion at times. So, it is very important for farmers to make sure not to lose their seed, otherwise they might end up with the wrong variety. Another disadvantage of borrowed or bought seed is that you cannot be sure about the viability and vigour of the seed.

Seed sources

For staple crops like millet and rice, seed markets do not exist, although occasionally farmers buy millet grain in the market and use it as sowing seed. The main disadvantage of buying millet seed in the market is that grain of early and late millet look very similar. For late millet, NGOs and NARI are not involved in seed supply. For rice, it is quite common for farmers to obtain seed from NGOs or extension workers, but more commonly obtain seed through the informal system (Table 6.2). The informal system comprises relatives, friends and other farmers. The formal system usually distributes seed and varieties on a project basis. The different percentages in Table 6.2 are due to rather localised NGO-projects in the country. The activities of the formal sector can even differ between villages in the same district (see Chapter 5). In Kitty extension officers have distributed seed several times, while the first time many women from Tujereng got substantial amounts of rice seed from the formal sector was in 2003. In some cases the farmers need to give back the same quantity of seed to the NGO as they received. If NGOs give seed to farmers, it is often on the initiative of the NGO, and not that of farmers.

Table 6.2: Farmers' seed sources for rice in various districts, in percentages (data from 2002-questionnaire).

seed source	Kombo	Foni	Kiang	Fuladu	total
# respondents	60	29	20	20	129
own seed only	17	31	20	15	20
informal system	65	24	65	35	51
formal system	13	10	5	35	15
both formal and informal	5	34	10	15	14

Women also exchange seed of different varieties with each other. Somebody who wants *Kari Saba* and has much *Binta Sambou* goes to other farmers with a bucket of *Binta Sambou* asking to exchange *Kari Saba*. The exchanged varieties do not necessarily need to be planted in the same ecology. It is also possible to exchange *faro* varieties with *tandako* varieties. The reason this system works is that women may need specific varieties for planting, but are willing to consume any suitable rice.

It is also a Muslim tradition to give part of the harvest (about 10%) away to other people, especially to the poor. When it is rice, the grain given away will be of a variety which gave a good harvest, and this can differ from year to year. Although it is meant for consumption, sometimes, people use this charity rice as sowing seed.

It sometimes happens that women give seed of an uncommon variety to other women to sow, if they know that in the next season they will not be able to grow rice, because of pregnancy or because they do not have a field available. In that way, they will have seed of that uncommon variety for the following season. This practice is not used for millet seed, because most people in one village grow the same variety.

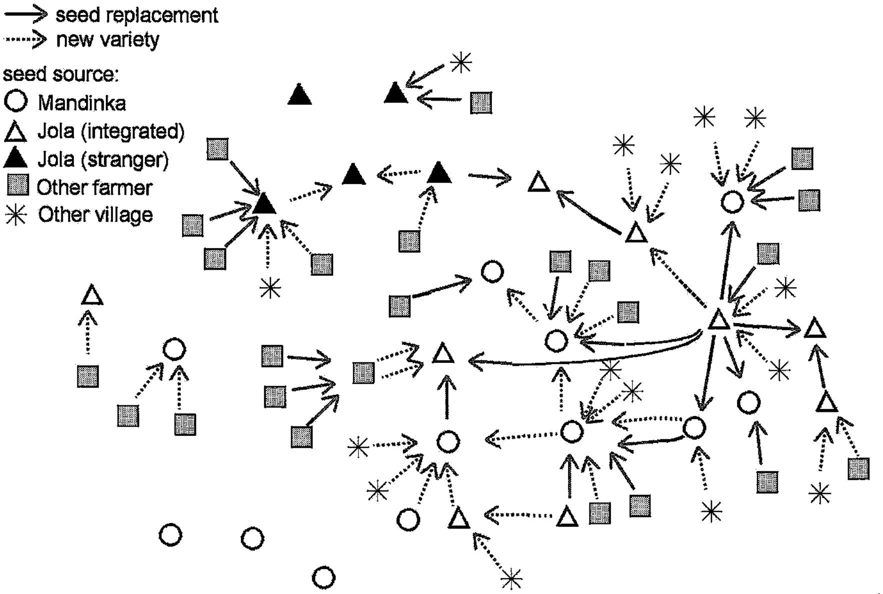


Figure 6.1: Sources for seed replacement and new varieties of the interviewed women of Tujereng (n = 26) over the years 2000-2003. Out of 26, 6 farmers indicated they had not borrowed any seed during this period.

For millet, transplanting seedlings is another option for farmers if they lack seed. They can use seedlings from their own field, and if that is not possible, go to other farmers and ask whether they can do the thinning for them. As long as farmers do this in their own village, the chances of getting plant material of the 'wrong' variety are very small. However, this means, theoretically, that these people do not have any 'control' over the 'genetic quality' or variety traits of the millet they plant. This disadvantage was not mentioned by any farmer, however. Furthermore, there is more certainty about the characteristics of thinned material from the same village than buying seed in the market.

In the lowlands, asking other women for rice seedlings for transplanting is possible but very uncommon. In 2002, one woman from Tujereng whose seed did not germinate well went to other farmers to find seedlings to transplant and she ended up with a complete mixture of different varieties in her field. This meant she had to harvest carefully to purify the sowing seed for the season of 2003.

Sources of new varieties

As when seed is lost, seed of new rice and millet varieties predominantly follows kinship or friendship lines. Particularly for late millet, NGOs and extension play a negligible role in distributing new varieties. When farmers move to a village, they often acquire millet and rice seed adapted to local conditions from people of that village. A few men said they bought millet grain in a nearby market for use as seed when they settled in a village. When men move to a new village and have obtained millet seed adapted to the local conditions, they usually do not look for other varieties. Women, however, often look for new rice varieties, even though they have some varieties adapted to the local conditions. Figure 6.1 shows that women acquire new varieties as often as they replace lost seed. However, whereas some women are very active in acquiring new varieties, others are not (Figure 6.1). These differences can be best explained by the amount of spare time and the level of personal interest in varieties and diversity. Women search for new varieties both within and outside their village (Figure 6.1). Most households have many affinal links to various places in the country, and hence women have many different seed sources, although it seems some particular links are more used as seed sources than others. Figure 6.2 shows from which places women from Tujereng, Kitti, Faraba and Janack obtained rice seed. The information on seed sources in Figure 6.2 was obtained through semi-structured interviews and does not give a complete overview but only an impression of women's networks. Figure 6.2 shows linkages exist between the four villages and that the furthest seed source in The Gambia was about 150 km away. Because The Gambia is a long, narrow country sharing borders with Senegal on three sides, many family ties run between The Gambia and Senegal and many women, particularly from Janack which is a Jola village, said they also got seeds from various places in Senegal. Two women who originally came from Guinea-Bissau said that they brought some of their varieties from their home villages in Guinea-Bissau. From a historic and ethnic perspective, probably farmers' networks on the south bank of the river Gambia are mainly eastward and southward oriented, while networks on the north bank are much more oriented to the east and north. Apparently, these wide networks do not guarantee that when conditions change farmers are always able to find varieties that match the new conditions (Box 6.1).

Another, rarer, seed source is exchanged rice seed contaminated with other varieties. When a woman sows such seed she detects another unfamiliar variety in her field at harvesting time. In that case she will harvest the off-type separate and test it the next year. Sometimes, women select completely strange off-types which they develop into new varieties (this will be further discussed in Chapter 7). Farmers also mentioned that women sometimes find viable seeds in bags of imported rice (see also Box 5.2 on *Binta Sambou*). To what extent bags of imported rice function as sources of new varieties is not clear.

It is possible that over time farmer seed networks have changed. With the construction of roads in the 1950s women's mobility improved. Likely, when minibuses started plying from the west to the east of The Gambia, women's seed networks further enlarged. Before groundnuts became commoditised in the 1830s, rice was a commodity, which it ceased to be in the later part of the 19^{th} century (Watts, 1993). It is likely that in those days, when rice was an important commodity, trade channels played an important role in the distribution of rice varieties. Nowadays, there is some trade in rice in the irrigation schemes near Jahally Pachar, but this is localised. It seems unlikely trade channels play a major role in the distribution of rice varieties nowadays. Since the increase in groundnut trade, trade in millet grain has decreased. However, because no millet is imported, trade in millet is still common country-wide, unlike the local trade for rice in the irrigated areas. The commonness of millet trade, to some extent, explains why men sometimes buy millet grain for seed, whereas women do not in the case of rice.

Other possible distribution channels for varieties include seasonal labour migrations as described in Chapter 2. With the decline in groundnut prices, it seems likely that seasonal migration will have decreased in importance as a channel of variety supply. From the 1950s onwards, the Gambian government and, from a later stage, various NGOs function as channels for variety distribution. Farmer seed networks are also fuelled by the many research trials conducted throughout The Gambia and Senegal.

Box 6.1The origin of *Kari Saba*

Kari Saba is the first 3-month (farmer) variety that entered the seed system of the village of Tujereng and probably because of that, farmers eventually called it *Kari Saba Mano* (3-month rice). Kari Saba was brought from Casamance in the early 1970s, just before the onset of the first droughts, and its biggest advantage was that it was high yielding and flowered early. So, almost simultaneously with the first droughts of the early 1970s, farmers of Tujereng came across 'new' farmer rice varieties with shorter durations than the 'old' farmer varieties. Some farmers said that when *Kari Saba* was brought to the village, they first thought it was a waste of rain, because it matured so early. In the 10 years following its introduction, other short duration varieties (both formal and farmer) entered the Tujereng, but none proved to be as successful as *Kari Saba*.

To say that farmers can manage during periods of drought based on the influx of farmer varieties would be too positive a story. In the village of Janack for example, the droughts forced farmers to stop rice cultivation, even though farmers from Janack had equal opportunities to find new varieties with the farmers from Tujereng. The main, and probably only, difference between the two villages is that the average rainfall in Tujereng is higher than in Janack, and that the droughts had a much larger impact in Janack than in Tujereng. A more crucial factor might be luck: Farmers in Tujereng happened to come across new suitable varieties at the right time, whereas farmers in Janack did not. This would imply that an effective extension system is important to provide farmers with better varieties that fit changing ecological conditions.

Seed supply by NGOs and NARI

When NARI (the National Agricultural Research Institute) was set up in 1924, it was to deal primarily with groundnut cultivation (Barrett, 1988). Probably, the first time the state provided groundnut seed was in the early years of the 20^{th} century after droughts (Swindell, 1992). Until today, groundnut is still one of the main crops NARI focuses its research on and for the Seed Technology Unit (STU) it is the most important crop. Because of the development of irrigation schemes and government plans to become self-sufficient in food production, rice is the other crop that receives a lot of research attention.

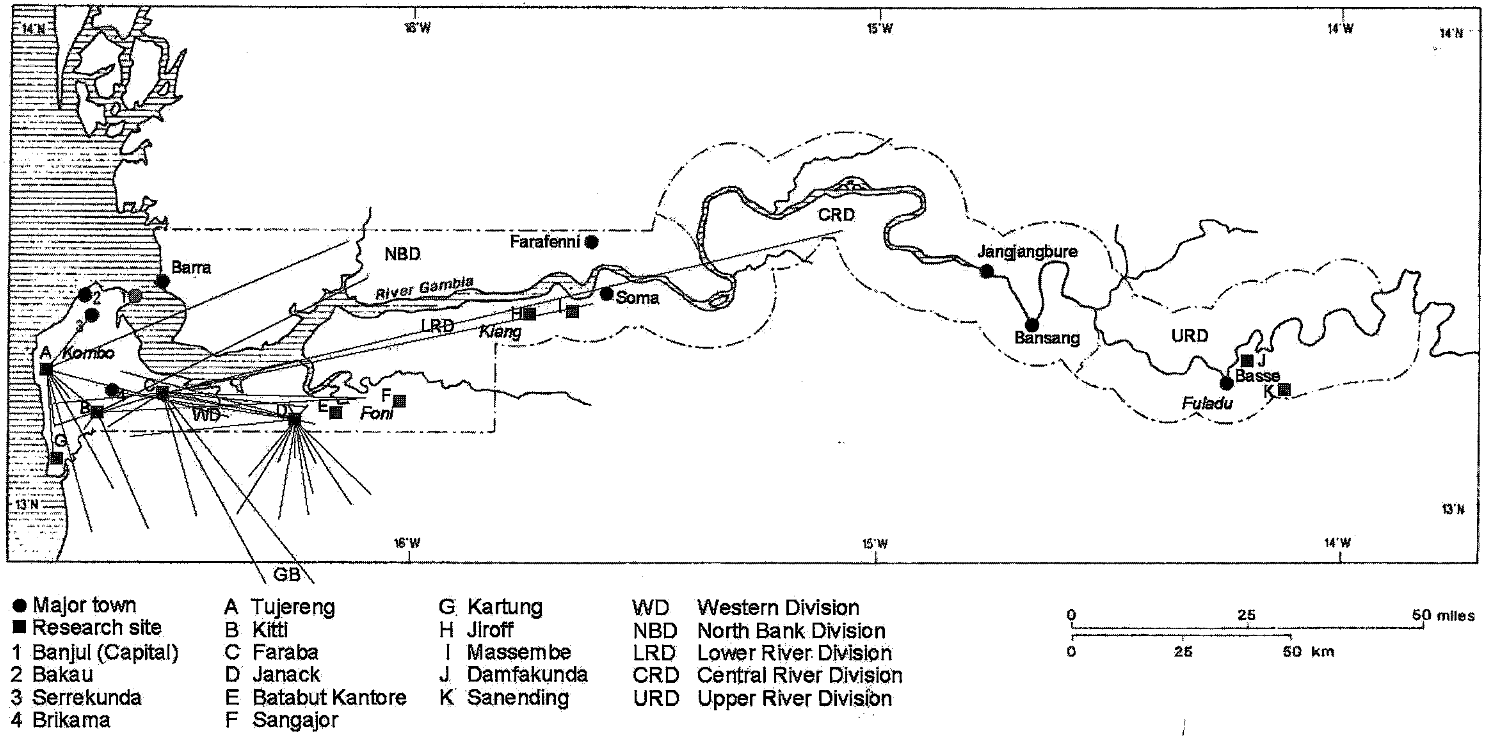


Figure 6.2: Rice variety sources for the villages Tujereng, Kitti, Faraba and Janack, indicated by solid lines. Lines pointing toward Casamance do no indicate the exact source. GB stands for Guinea-Bissau where 2 farmers collected seed.

The Gambia Produce and Marketing Board (GPMB) was the other institution involved in the supply of groundnut, but this came to an end in 1985 due to the subsidy cuts following the Economic Recovery Programme in 1985 (Cromwell *et al.*, 1993). Nowadays, STU is the only institute involved in the multiplication and supply of groundnut and cereal seed. STU envisages that rice yields will increase if farmers buy quality rice seed from STU. But till today, the majority of rice farmers are self-seed sufficient, which also has a positive side in that it allows the development and spread of new genotypes (see Box 5.2). Due to institutional and logistical constraints, it would be simply impossible for STU to supply rice seed to all farmers in The Gambia. This was accentuated by a radio broadcast in October 2003, in which the minister of agriculture advised farmers to save their own seed for the next season. Not being able to organise the formal seed sector is not only a typical problem for The Gambia, but for many West African countries (Richards, 1985; Ndjeunga, 2002).

At the moment, STU multiplies seed if there is a demand from NGOs and other government institutions. NGOs are the main distributors of new varieties, mostly in areas dependent on rainfall, and they also ask STU for advice which varieties to distribute in which areas. Another distribution channel is the Soil and Water Management Department (SWMD), which falls under the government. SWMD builds barriers and dikes to expand the rice-growing areas, and at the same time distributes formal rice varieties adapted to the sometimes changed growth conditions.

Information about officially released rice varieties is limited. Appendix 5 contains a list of varieties adapted to the uplands and transitional zones, of which some were officially released by NARI. The list shows only nine released varieties, although in the past many varieties have been tested, of which many seemed to show much potential (DOA, 1986; NARI, 1992; 1993; 1994; 1996; 1998). For some of these varieties, it is known at which institute they were developed, but for other varieties, like *CCA*, *Peking* and *Rasi*, only the country of origin is known (Appendix 5). The main reason for other varieties not to have been released is discontinuity in the process of variety testing, which relies on donor funding. It takes at least six years to test and officially release varieties whereas projects usually last for shorter periods. In addition, there are storage and dissemination problems. Many varieties tested in farmer field trials were 'stolen' by farmers (Drammeh, personal communication). Which varieties exactly were stolen and which then spread successfully is unknown.

Of the nine varieties shown in Appendix 5, some are being multiplied and distributed, while others are not but can still be found in farmers' fields. Three varieties in Appendix 5, *CCA*, *Peking* and *Rasi* were among the samples collected from farmers. Besides these three varieties, *Parasana* is still being multiplied by STU and distributed in upland areas and transitional zones today. *Se 302G* and / or *Se 319G* can still be found in farmers' fields, but are not multiplied anymore. No seed is available anymore of the variety *DJ 11-509* because the foundation seed stored in Djibelor has almost been lost because of the rebel war in Casamance. Whether it is still present in farmers' fields is unclear. The variety DJ 12-519 is still distributed but has become contaminated with other varieties. Whether the variety *WAB 56-50* is already distributed is unclear. According to STU it has not yet been released. However, the NGO Sint Joseph Family Farm claimed it distributed this variety in Janack. One sample found in Janack is similar to *WAB 56-50* (but has different flowering period) and might be related to *WAB 56-50*.

Apart from farmers travelling to neighbouring countries and returning with formal varieties, some NGOs also have been to Senegal to obtain rice seed to distribute to Gambian farmers. During the droughts of the early 1980s many farmers lost their rice seed and the NGO Freedom From Hunger Campaign went to Casamance to buy new seed to give to farmers who had lost their seed stock (Joof, personal communication). The NGO does not know the names of those varieties. Its people only made sure that the varieties they distributed were suitable for the ecologies in which they were distributed. During this search they did not keep records and did not differentiate between farmer and formal varieties.

6.4 Variety naming

Naming mechanisms

Rice

There are many different ways of naming rice varieties:

- To name the variety after the woman, extension officer or organisation a farmer acquired it from
- To name the variety after the village or region where a farmer acquired it from
- To describe a particular morphological characteristic, like husk colour, plant length, presence of awns, grain size or grain shape
- To describe agronomic characteristics like growth duration or the capability to suppress weeds
- To label cookery characteristics like taste
- To give a variety the same name of a variety it resembles in a particular characteristic
- Women sometimes pick out a different variety from an already known variety and call the new variety *Tombon Mano* (selected rice).
- In the case of formal varieties, the name is often modified, to make pronunciation and remembrance easier. For example, *Terwiet* probably refers to the formal variety *IR 8*, when pronounced in French (Suso, personal communication).

Because many varieties have a white husk colour, different varieties often have the same name, *Mani Koyo* (= white rice). I asked some women whether they knew the names of some off-types I collected. Since some of them had a straw husk colour, with a black tip on top, four of these off-types were given the name *Sefa Nunfingo* (= black nose) by the women, although they were different in other morphological characteristics.

Other examples illustrate how several varieties get the same name or how one variety gets several names:

> As a reaction to the decrease in rainfall, the Soil and Water Management Department started building dykes in the lowlands to extend the area and season for rice cultivation. At the same time they introduced several formal varieties. These varieties can all be called *Baras* by farmers. One woman explained that in their village three varieties have the name *Baras*. *Baras* is supposedly derived from the Portuguese word for dyke.
>
> The variety *Binta Sambou* was discovered by the woman called Binta Sambou, and everybody in Tujereng now calls this variety *Binta Sambou* (Box 5.2). The variety was taken to other places, like Kitti where it is called *Tujereng Mano*. From Kitti it was brought to other places like Madina Silaam and Faraba where a woman called it *Mani Koyo*, because of the whitish husk. Another woman in Kitti calls a different variety *Tujereng Mano*, because it resembled in husk colour and grain shape the original *Tujereng Mano* (*Binta Sambou*).

> After the introduction of the formal variety *Peking* in the late '1960s, other varieties were introduced with the same short stature, grain shape and husk colour as *Peking*. In many occasions, these varieties are also called *Peking*, or *Mani Suntungo* (short rice) or *Chinese Mano* (because *Peking* is thought to originate in China).

A woman may change the name of a new variety several times, till she finds a name she likes. JJ in Tujereng got a rice variety from Jokadou on the North bank, and called it *Jokadou Mano*, after the place of origin. The next year she called it *Bali Mano*, because the wider area is known as Bali. KJ called a rice variety with small grain *Mani Tereyengo* (quick rice), but the year after that she changed the name to *Badibu Mano*, after the place of origin.

It is also possible for women to call the same variety different names at the same time. Some women in Tujereng only plant 2 varieties in their field: *Kari Saba* and *Binta Sambou*. Because *Kari Saba* has a reddish husk colour and *Binta Sambou* a whitish husk colour, they also call *Kari Saba 'Mani Wulengo'* (red rice) and *Binta Sambou 'Mani Koyo'* (white rice).

The most important guidance in giving names for the women is that they can distinguish the rice for themselves and they understand each other when discussing different varieties of rice.

From the above, it seems there is no system in variety naming, but there might actually be much more logic than apparent at first. If Tujereng is considered, all old varieties refer to a morphological characteristic; *Sefa Koyo* owes it name to its white husk colour, *Sefa Fingo* to its blackish husk colour, *Hombo Wulengo* to its red husk colour and *Kukur* to its big seed size. More recent varieties like *Binta Sambou* and *Sonna Mano* are named after the women who introduced or found these varieties. The variety *Barafita* which was introduced by an extension officer called Banghura early 1980s was called *Banghura* instead of *Barafita* by Tujereng women. Also the variety *Kari Saba* (3-month) which was introduced 30 years ago was at first named after at least one woman. Several women claim they are responsible for the introduction of *Kari Saba* to Tujereng. Possibly because it was the first 3-month variety introduced, it eventually became named *Kari Saba*.

So, it seems that introductions of completely new rice varieties into a village that are adopted by many other farmers of the same village are named after the person who found or brought the rice variety to the village. This can also be seen as a credit given to the person who introduced that variety. After a period of time, maybe 20 years or so, the variety gets a new name based on its distinctive morphological traits. Therefore, old varieties only have names based on their morphological appearance. (This also would mean that the naming system is an unconscious system for maintaining genetic diversity: varieties need to be morphologically different for the naming system to work). The fact that some women call *Binta Sambou* '*Mani Koyo*' might mean that the variety is already in the process of moving from new to old rice. Completely new varieties introduced by farmers but not adopted by other farmers carry names of any sort, at the cultivator's vagary. In regard to names, therefore, we can refer to old, new and idiosyncratic vices.

<u>Millet</u>

For millet, variety naming is somewhat different from that for rice. First of all, the Mandinka name for millet is '*nyo*' and refers to pearl millet, sorghum and maize. So, if you want to indicate pearl millet specifically, you have to clarify this. But there is no generic name in Mandinka that refers to pearl millet as such. Each millet type has its own name: Early millet is called *suno*, one type of late millet is called *sanyo*, and the second type of late millet is called *majo* or *majo dabel*, which is grown only in the east and does not have bristles unlike *sanyo*.

Some farmers, however, also refer to the last type as *sanyo*. So the distinction between *sanyo* and *majo* is less clear than between *sanyo* and *suno*.

Each millet type has several varieties. When you ask what kind of variety a farmer grows, in most cases he will only say he is growing *sanyo* or *suno*. In some cases, he will specify according to morphological characteristics (like grain colour, or spike length) or to the area where it is grown a lot, like *Foni nyo*. Some of the early millet varieties are formal materials, of which farmers modify the names to make pronunciation and remembrance easier, like for rice. Because there are fewer millet varieties than rice varieties, one might think that nomenclature for millet is more consistent. The following sections illustrate that this is not true.

Consistency in variety naming of rice

Variety names can be very confusing: The same name can refer to different varieties and different names to the same variety. The samples collected during the interviews in 2000 and 2002 were compared to understand which varieties were more common, to what extent name giving was consistent, which varieties were grown in multiple villages and to what extent the names of the same varieties grown in different villages were the same.

Table 6.3 shows, per village, the number of farmers who gave samples, number of collected samples, total number of names mentioned, total number of names farmers gave to the samples and number of varieties identified per village. The assumption was that the number of varieties grown in the field would be much less than the number of varieties based on the names given by farmers. In total, 129 different names were given to 297 samples. The number of varieties identified is 102, which is only 80% of the total number of variety names. This percentage varies between villages. Some varieties were given different names, while some names were given to different varieties. In Jiroff, for example, 11 varieties were identified, while the names linked to the samples indicated 15 varieties. In Massembe 11 varieties were identified and 10 names given.

Table 6.3: number of varieties per village, based on farmer variety naming and morphological identification (data from 2002-questionnaire combined with data from 2000-interviews).

village	*interviews*		*samples*				
	# farmers	# variety names	# farmers	# samples collected	# variety names	identified # varieties	difference in # varieties[1)]
Jiroff	10	17	10	28	15	11	-4
Massembeh	10	12	9	29	10	11	1
Batabut	10	7	7	11	5	5	0
Kartung	10	11	8	19	9	7	-2
Sanending	10	7	8	16	4	5	1
Faraba	27	34	22	51	26	23	-3
Kitti	27	37	21	46	27	29	2
Sangajor	10	18	9	17	12	10	-2
Janack	10	29	10	28	22	18	-4
Tujereng	37	32	25	52	25	25	0
total	161	163[*)]	129	297	129[*)]	102[*)]	-27[*)]

[*)] = Total is not the sum of the villages because of overlap in variety use among villages

[1)] Difference between '# variety names' belonging to the samples and 'identified # varieties'

When analysing the samples, it became clear that some villages have a more consistent name use than other villages. Table 6.4 shows to what extent names refer to varieties in a consistent way. Table 6.4 shows the number of names linked to the samples collected per village and the number of names which were consistently used, the number of names that show some consistency and the number of names that were not consistently used. Because of too few samples, Damphakunda was excluded from the analysis.

Table 6.4: Consistency of name use for rice varieties by comparing varieties per given names (does a name refer to varieties in a consistent way?) within villages (data from 2002-questionnaire combined with data from 2000-interviews).

village	# samples	# variety names	single names[1] (N)	single names[1] %	consistent names[2]	somewhat consistent names	not consistent names	% consistent names[3]
Jiroff	28	15	9	32	5	1		33
Massembeh	29	10	4	14	5	1		50
Batabut	11	5	3	27	2			40
Kartung	19	9	6	32	3			33
Sanending	16	4	2	13	2			50
Faraba	51	26	15	29	3	2	6	12
Kitti	46	27	15	33	3	4	5	11
Sangajor	17	12	9	53	1	1	1	8
Janack	28	22	17	61	3	1	1	14
Tujereng	52	25	10	19	10	2	3	40

1) = # names that are represented by single samples
2) = # names that are consistently used, somewhat consistent, or not consistent (If the samples with the same names were all linked to the same variety, the name was added to the column 'consistent'. If 2 out of 3 or 3 out of 4 samples were linked to the same variety, the name was added to the column 'somewhat consistent'
3) = Consistent names / # variety names * 100

Table 6.5 combines a summary of Table 6.4 with some other variables like common rice ecology, percentage of farmers who borrowed seed in the past 5 year, number of varieties commonly grown and area occupied by the 2 most common varieties. Variety naming is most consistent in those villages where farmers work in flooded lowlands (Table 6.5). In Tujereng, where most farmers work in the uplands, variety naming is also quite consistent. Least consistent is variety naming in Sangajor and Janack, where farmers work mostly in the transitional zone. Table 6.4 also shows that the number of single entries for which only one name was linked to one sample was very high for Janack and Sangajor. In Kitty and Faraba, where farmers work both in flooded lowland and the transitional zone, variety naming is more consistent for the varieties planted in the flooded lowlands than for those sown in the transitional zone, but not as consistent as in those villages where farmers only grow rice in flooded lowland.

In those villages that have consistent name use (Massembe, Batabut, Kartung, Sanending and Tujereng), 2 or 3 varieties are commonly used by almost all farmers, while other varieties are only used by a few or sometimes single farmers (Table 6.5). In Jiroff there is more of a continuum in variety use, but 4 varieties are more common. In the villages of Kitti, Faraba, Janack and Sangajor it is more difficult to say which ones are the common varieties.

In general, those villages where farmers do not often lose seed have a more consistent name use than villages where farmers lose seed very often (Table 6.5). Those villages whose farmers lose seed often have in common that farmers work in the upper sequence of the transitional zone. That part of the transitional zone is more drought prone than the lowlands and the uplands because it is often not flooded (like the lowlands) and it has a clayey texture (unlike the uplands) which decreases the water uptake by plants under drought conditions.

Hence, in a village like Janack, where farmers suffer from bad harvests frequently, it is more difficult for farmers to assess which varieties perform best. Hence, also at village level it is not clear which varieties perform best. Another factor that is directly related to variety naming is the distribution of varieties by the formal sector, which is different from the distribution of varieties in a farmer system. If farmers adopt a new variety introduced by a particular farmer through the informal system, it is only one variety at a time. If many farmers adopt that variety from the same farmer, all farmers will name the variety after the same farmer. If that happens, the chances of name confusion are very small. If an NGO distributes several varieties simultaneously to farmers in a village, farmers cannot name all varieties after the name of the person working for the NGO. This contributes to name confusion. In Faraba three varieties share the name *barass* (after the governmental department that built dykes in their rice fields). In Kitty, at least two varieties share the name *Worldbank.* Another aspect contributing to name confusion is that formal varieties look very similar (see Chapter 10).

Table 6.5: Summary of research on number of identified varieties, consistent naming of rice varieties, # common varieties, % of farmers borrowing seed in the past 5 years, area occupied by 2 most common varieties (in %) and percentage of farmers who got seed through the formal sector (data from 2002-questionnaire combined with data from 2000-interviews).

village	rice ecology [1]	identified # varieties	consistent name use	% farmers borrowed seed in past 5 year	# varieties commonly grown	area occupied by 2 most common varieties (%)	% farmers got seed from formal sector
Jiroff	mangrove	11	a lot	20	3 – 4	44	30
Massembeh	mangrove	11	yes	10	3	43	0
Batabut	lowland	5	yes	10	2	86	30
Kartung	lowland	7	yes	0	2	77	0
Sanending	lowland	5	yes	10	2	73	40
Faraba	lowland + trans zone	23	no	41	not clear	37	39
Kitti	lowland + trans zone	29	no	28	not clear	24	25
Sangajor	trans zone [2]	10	no	56	not clear	56	50
Janack	upland / trans zone	18	no	67	not clear	31	56
Tujereng	upland / trans zone / lowland	25	a lot	30	2 *)	89*)	0

[1] = Most common ecology in the particular villages; + = many farmers work in both ecologies; / = farmers grow in either one ecology. In lowland (except in Tujereng), rice is mostly transplanted, whereas in the transitional zone, rice is mostly broadcast.
[2] trans zone = transitional zone
*) = for upland and transitional zone only

Name consistency between villages

In this section the question is addressed to what extent varieties grown in different villages are the same, and whether their names are the same. To what extent do villages have separate sets of rice varieties, and if so, do farmers use the same names for these varieties? Since farmers from different villages do exchange varieties, but rename them, each village is expected to have a distinct set of variety names.

Table 6.6 shows the number of identified varieties per village, and the number of rice varieties that these villages share with each other. The number between brackets indicates of how many shared varieties the same name is used in the respective villages. Appendix 6 gives a detailed list of the varieties villages share. In Table 6.6, the villages are put in sequence according to their topographic position, from west to east (see Figure 6.2 for the locations of the villages).

Further, per village, the main ecology is indicated: The higher the number, the more important that ecology in that village. Equal numbers indicated equal importance.

Table 6.6 shows that some villages share many varieties while others share only few. On average, villages share 9% of their varieties with other villages, which means that each village has a quite distinct set of varieties. To some extent this can be explained by ecological differences and similarities. However, one would expect that the villages Jiroff and Massembe, about 25 km apart, would share many varieties, since they also share the same ecology, but they use different sets of varieties. Another factor that explains differences in variety use between villages is the difference in prevalence of diseases and pests. Blast, for example, is a much bigger problem in the western part of the country than in the eastern part, to the effect that in the western part only blast resistant varieties can be grown. Probably, the most crucial factor in explaining differences in variety use is that contacts between farmers are more frequent within villages than between villages.

This probably accounts for the fact that, while within villages there can be clear name consistency there is hardly any name consistency for the same varieties grown in different villages (see the numbers between brackets in Table 6.6). It happens that names are used consistently within different villages for different varieties. Apparently, what matters most for farmers is that they understand each other within a village. Furthermore, if a farmer gets a variety from a different village she gives a new name to that variety. The result is that although villages are linked to variety sources in the outside world, mostly via marital ties, each village not only has its own set of varieties, but also its own set of names.

Table 6.6: Number of identified rice varieties per village, the number of varieties that these villages share with each other and the number of varieties for which the same name is used (between brackets). The villages are listed according to their geographical position from west to east (data from 2002-questionnaire combined with data from 2000-interviews).

division	WD	WD	WD	WD	WD	WD	WD	LRD	LRD	URD
main ecology *)										
upland	2				2					
trans zone	1	1	1	1	2	1	2			1
lowland	1	2	1	1		2	1			2
mangrove								2	2	
village	Tuje-reng	Kartung	Kitti	Faraba	Janack	Batabut	Sang-ajor	Jiroff	Mas-sembeh	Sanen-ding
Tujereng	25	1(-)	8(-)	4(-)	4(-)		2(-)			1(-)
Kartung		7	3(1)	1(-)		1(-)			1(-)	
Kitti			29	12(2)	5(-)	1(-)	5(-)		1(-)	
Faraba				23	6(3)	1(1)	4(2)			
Janack					18		3(-)			
Batabut						5				
Sangajor							10			
Jiroff								11	1(-)	1(-)
Massembeh									11	
Sanending										5

*) = The higher the number, the more common the particular ecology is in the village

Name consistency in millet

As was mentioned in Chapter 5, in each village most farmers grow the same variety of millet. Table 6.7 gives an overview of the varieties grown in the various villages. The villages are listed from west to east. Table 6.7 is based on information from interviews, seed samples and data from the trials described in Chapter 10.

Table 6.7: Millet varieties, and their characteristics, most commonly grown in the case study villages; from west to east (combined data from 2002-questionnaire and 2000-interviews).

village	district	millet type	common name	bristles	seed colour	spike length
Tujereng	Kombo	late	*Sanyo*	yes	grey	short
Kartung	Kombo	late	*Sanyo*	yes	-- 1)	-- 1)
Kitti	Kombo	late	*Sanyo*	yes	white	long
Faraba	Kombo	late	*Sanyo*	yes	mostly grey	long
Janack	Foni	late	*Sanyo*	yes	white	long
Batabut	Foni	late	*Sanyo*	yes	white	long
Sangajor	Foni	late	*Sanyo*	yes	white	long
Jiroff	Kiang	early	*Suno*	no	brownish	long and short
Massembeh	Kiang	early	*Suno*	no	brownish	long and short
Damphakunda	Fuladu	late	*Majo*	no	brownish	long or short
Sanending	Fuladu	late	*Majo*	no	brownish	long or short

1) = no information available

In Tujereng and Faraba farmers grow two different varieties of late millet which are both black seeded, while in Kitti and all villages in Foni farmers grow the same variety of late millet which has white seed (more detailed information in Chapter 10). In Sanending and Damphakunda farmers grow *majo*, a late millet variety without bristles and with brownish seeds. According to farmers, two varieties of *majo* exist, one with long spikes and one with short spikes, but the measured samples did not differ in spike length (see Chapter 10) and it is not clear how common each of these varieties is. In Jiroff and Massembe farmers also mention that they know of two varieties of early millet, which are both grown in each village, one with long spikes and one with short spikes. From Table 6.7 one might conclude that there are more late millet than early millet varieties, but this is due to sampling and according to NARI-researchers more early millet varieties exist than late millet varieties. Also, the area under early millet cultivation is much bigger than that for late millet (see Chapter 2).

As explained in the methodology, for millet, samples were not collected to compare them with variety names during the questionnaire in 2002. In the villages Tujereng, Kitti, Faraba and Janack detailed questions were asked on the variety names alongside the sampling for the morphological study described in Chapter 10. One would expect that since fewer millet varieties exist than rice varieties, there is less name confusion for millet than for rice. However, even though most farmers growing the same late millet variety call it *sanyo* they give different descriptions. Other farmers use different names to indicate the same variety. If farmers' descriptions are followed, one would conclude that three times as many varieties are grown than is actually the case (Table 6.8). This means that millet names tend to overestimate the actual variety number somewhat more for millet than for rice. One explanation might be that since most farmers in a village grow the same variety there is also less need for consistent name use and variety description.

Almost all farmers who never replaced their variety call it *sanyo*, irrespective of whether it is black or white, and whether it has long or short spikes. This naming practice would lead to an underestimation of the actual number of late millet varieties. Those farmers who have replaced their variety also call the new variety *sanyo* in most cases. But 38% of them call it differently, even while, usually, referring to the common variety of the village. Those farmers use names like *Tujereng nyo*, *serengo*, *komba*, *majo* or *majo koyo*. *Serengo* is the name of a dish, which is made from *white sanyo*. *Majo* is actually the common variety grown in Fuladu, which does not have bristles. So, variety replacement increases the number of variety names farmers know or use, in that way contributing to the overestimation of the actual number of varieties.

Added to this is an interesting difference in the number of late millet varieties farmers claim exists (Table 6.8). Farmers who replaced their varieties more often tended to know more late millet varieties (spearman rho correlation: 0.423, $p = 0.001$, $N = 49$). Many farmers in Tujereng and Janack say only one or two varieties exist. In Tujereng and Janack most farmers still grow the same variety their father used to grow. In Faraba and Kitti some farmers say up to 5 different varieties of late millet exist. These farmers first subdivide late millet into *sanyo* and *majo*, which are both further subdivided. It is also interesting to note that even those farmers who differentiate late millet into 4 or 5 varieties say that millet is millet. Morphological analysis shows that the only obvious differences are bristle length and seed colour. Agronomic performance does not seem to differ much.

One would expect that if farmers move from one place to another they would be exposed to different millet varieties and consequently know more varieties, but there is no clear correlation. Some farmers who fled from the war in Casamance and settled in Kitty did change varieties. Other farmers who settled in Kitti many years ago only replaced *black sanyo* with *white sanyo* in the last 10 years, because they think it is better adapted to low soil fertility. In Faraba many farmers settled 30-40 years ago and some farmers had to switch varieties because the one they had did not grow well in Faraba. Other farmers who moved to Faraba did not change varieties, and hence, did not increase their knowledge about millet varieties.

Table 6.8: Average number of millet varieties farmers know in each village, number of variety names given and number of varieties identified in each village, and percentage of interviewed farmers who replaced their variety and percentage of strangers in the village (data from 2000-interviews).

village	# farmers (N)	# varieties known average	range	# names given	# varieties identified	% farmers replaced variety	% strangers
Tujereng	29	1,7	1 – 3	5	1	18	32
Kitti	6	2,7	2 – 5	4	1	100	100
Faraba	9	2,7	1 – 5	3	2	56	89
Janack	8	1,9	1 – 3	3	1	43	29
total	52	2,0	1 – 5	10	3	37	50

6.5 Discussion

In this chapter information is presented on seed loss, seed sources, variety sources, variety naming, consistency in variety naming and common varieties.

Seed loss and seed sources

Results show that broadcast rice seed is more often lost than millet seed, but transplanted rice seed is less often lost than millet seed. Whereas for rice, drought is the most common cause of seed loss, for millet, birds and blister beetles are the most common causes of seed loss. Another factor that is different between rice and millet is that if women fall ill during harvesting they might lose their seed, whereas, for millet, this was not mentioned, and because of the different organisation of labour (see Chapter 2) is also unlikely to happen. Minor factors that cause seed loss for both rice and millet are storage pests and that seed is eaten or not enough is stored.

For both millet and rice, access to seed is usually not a big problem, but for both crops, farmers stress the importance of seed saving. In Northern Nigeria Busso *et al.* (2000) also found that farmers, unless experiencing crop failure, did not generally exchange seed with neighbours. In the case of millet, this can be explained by the fact that varieties are difficult to differentiate after threshing, and in the case of rice, it is not always possible to replace uncommon varieties.

To a large extent, seed sources in The Gambia are comparable with other West African countries. For both rice and millet, family members and friends in the same village are the main seed sources and no commercial seed market exists. For millet, a few farmers buy grain in the market and use it as seed. This is also reported for Senegal (Osborn, 1995). The picture is similar in Niger, where in years with drought up to 14% of farmers purchase seed from local market, but in years with adequate rainfall farmers rely on their own seed stock (Ndjeunga, 2002). For rice, Gambian farmers sometimes get or buy seed from NGOs or extension, but do not buy seed in the market. In Sierra Leone, however, buying rice seed is as common as borrowing or exchanging seed (Richards, 1986).

Variety sources

The information in this study shows that farmers find seed of common rice varieties in their own village, while the seed they obtain from other places is usually meant for experimentation. Seed quantity is an important aspect, since seed quantities needed for the replacement of common varieties are large while for testing varieties small quantities will suffice. When farmers see an interesting rice variety in other fields they sometimes 'steal' a few panicles. Similar practices for maize in Oaxaca in Mexico are described by Badstue *et al.* (2002). Because it is common for women to marry outside their villages, their networks for rice seed outside the village are extensive, more so than for millet. Some women take rice seed of 'strange' varieties with them when visiting family members who live as far away as Guinea-Bissau. For millet, although some men sometimes also take seed with them, this is less common and can be explained by the fact that fewer millet varieties exist than rice varieties (see Chapter 5). Furthermore, if men obtain seed from another village, it is usually the same variety they already have and is meant for seed replacement. It is sometimes argued that wealthier farmers are more likely to look for and test varieties (McGuire, 2005; Dennis, 1988). However, searching for and testing varieties seems to be influenced by various factors. From this case study available time, personal interest in diversity (Prain, 1994) and farming styles (see van der Ploeg, 1994) seem to be the crucial factors determining farmer experimentation. But indeed, wealthier farmers often have more time available.

There also seems to be a relation between the frequency with which men and women look for varieties of millet and rice respectively outside their villages and the degree of overlap in variety use between villages. This shows clearly in Western Division, but less clearly in Kiang and Fuladu. But note that for the latter two areas less data are available. For rice, there is some (varying) overlap in variety use between villages. For millet, almost all farmers of a village use the same variety and in some cases there is an almost complete overlap in variety use between villages while in other cases there is no overlap at all. Whereas for rice, women find 'new' varieties in distant villages which sometimes they spread within their village, for millet, men mostly use the variety they find in their village and do not go to other villages to find 'new' varieties. This implies that variety management of rice is more dynamic than that of millet. This does not mean that gender is the key factor, but rather the fact that many more rice varieties exist than millet varieties, the result of differences in breeding system of the two crops. Because a wide range of rice varieties exists and because new rice varieties develop continuously, it is possible for women constantly to search for better rice varieties, whereas there are only a few millet varieties and new varieties rarely develop. In Sierra Leone, where rice is grown by both genders, both men and women search for better varieties (Richards, 1986). This will be discussed further in Chapter 9.

Variety naming

For efficient seed exchange variety naming is important. The mechanisms for variety naming of rice and millet names are similar. Most commonly, varieties are named after the place of origin, after the person who introduced it or after agronomic, morphological or cookery traits.

In Tujereng three groups of names can be identified for rice varieties. Names of commonly used old rice varieties refer to plant characteristics. Names of commonly used new rice varieties, less than 30 years old, refer to the person who introduced and spread the variety. There is a third group of rice varieties, which can be both old and new varieties not widely used and for which there is no systematic naming. This implies that, within a village, names of varieties change depending on their popularity and the number of years that they are cultivated. In this way, the variety name can give information about the period of time it has been cultivated in a village.

One clear difference between rice and millet seems to be that rice varieties are named after people while millet varieties are not. However, as indicated for rice, varieties eventually carry names based on their morphology. Another difference between rice and millet is that women find or introduce new rice varieties quite frequently whereas this is not common for millet. So, the actual reason that millet varieties are not named after people is that only very rarely are new varieties introduced, whereas for rice this happens quite frequently. This then means that the naming systems for rice and millet differ as the result of differences in the rate of new introductions of varieties, which in turn is related to the different breeding systems of the two crops. Replacement of millet varieties occurs rather at an intergenerational scale, whereas for rice, farmers replace several varieties in their life (see Chapter 5).

Not a lot of research has been conducted on this topic at such detailed level. The literature sources found do not contradict the above system of variety naming. In Sierra Leone it is also common for farmers to name a variety after the person who introduced that variety (Richards, 1995). In Malaysia, Thailand and Lao PDR rice farmers mostly use agronomic and inflorescence related morphological traits to name rice varieties (Lambert, 1985; Dennis, 1988; Appa Rao *et al.*, 2002a). In Lao PDR varieties are also named after animals, birds, fish, flowers and fruits (Appa Rao *et al.*, 2002a). For sorghum in Ethiopia predominantly inflorescence related traits were used in naming varieties (Teshome *et al.*, 1997), but names also refer to place of origin (McGuire, 2005). In the Andes potato farmers use tuber shape and colour in many variety names (Brush *et al.*, 1981). In Malawi farmers use seed characteristics, place of origin and plant architecture (climbing or non-climbing) to describe bean varieties (Martin and Adams, 1987).

However, there are also farming systems in which plant morphology plays a less important role in naming. In the Peruvian upper Amazon the Amuesha often name their cassava varieties after birds, mammals, reptiles, insects, spiders and snails (Salick *et al.*, 1997). The varieties are not given their names by the cultivators but by the cassava ancestors who were people. The Amuesha believe that before the beginning of this world, cassava were people and that at the end of this world, they will be people again. The names are revealed after a person self-induces a trance by not sleeping and chewing coca for days (Salick *et al.*, 1997).

Consistent naming

Since many more rice varieties exist than millet varieties, it was hypothesised that naming causes less confusion for millet than for rice. However, the collected data suggest it is rather the opposite. Even though many rice varieties exist, variety naming tends to be more consistent for rice than for millet. Exactly because so many rice varieties exist, consistent naming is important to avoid confusion.

Furthermore, non consistent naming can lead to an overestimation of varietal diversity. The collected rice samples were given 129 different names by farmers, but represented only 102 varieties. The names of the collected millet samples suggested that 3 times as many millet varieties existed as were actually found (see also Chapter 10). Results from different studies lead to different conclusions. In a study on beans in Malawi, the same varieties were given different names in different areas (Martin and Adams, 1987). In a study on rice naming in Lao PDR, however, it was thought that some collected varieties with the same name may be genuinely different varieties, particularly if they were collected in different districts (Appa Rao *et al.*, 2002b). In a study on Andean cultivated potatoes, it was found that different phenotypes were given the same name, leading to a slight underestimation of genetic diversity in farmers' fields (Quiros *et al.*, 1990).

Consistent naming of rice varieties differs between villages in The Gambia. The main characteristic of those villages where no consistent naming can be observed is that farmers grow rice in the transitional zone and have suffered seed losses very frequently. Another similarity between these villages is that farmers got seed and new varieties more often through the formal sector than farmers from other villages. Usually, farmers will name such varieties after the organisation they got the variety from, or after a person working for that organisation. However, NGOs often distribute several varieties at the same time, which does not fit farmers' traditional naming system, indirectly requiring farmers to improvise. A third common feature of these villages is that they do not have common varieties. Possibly also because of frequent seed losses, farmers were not able to find out which varieties perform best.

In a study on Andean potatoes it was found that consistent naming varies between farmers, which was partly attributed to the skills and knowledge of farmers, but also to the lack of enthusiasm or desire of some farmers to spend time on accurate identification (Quiros *et al.*, 1990). In the case of cassava in Peru the lack of consistency in variety naming between families can be attributed to some extent to the quite unique naming process of cassava varieties but also to the geographical isolation of the families (Salick *et al.*, 1997).

Consistent naming and common varieties

Given the huge number of rice varieties that exist, one would expect that in those villages where farmers do not lose seed very often the number of common varieties would be large. But they are not. In those villages with consistent naming 2-4 common rice varieties make up 70 to 80 percent of the total area. This is in agreement with other studies. Although in Ethiopia farmers plant many different sorghum varieties in the field, particular varieties are clearly more common than other varieties (Tunstall *et al.*, 2001). In a study on maize in Mexico, one variety occupied 51% of the area while the rest of the area was occupied by 25 varieties (Louette *et al.*, 1997). In another study on maize in Mexico one variety occupied also 51% of the total area (Bellon, 1991). In Central Africa farmers are known for using mixtures, containing up to 29 different bean varieties (Voss, 1992; Sperling 1992). However, in spite of the large number of bean varieties used by farmers, 3 varieties accounted for 50 to 90% of each mixture (Voss, 1992).

Consistent naming between villages

Very little consistency exists in rice variety nomenclature between Gambian villages. It is common for farmers to rename varieties when they bring them to their own village, usually calling the variety after the person, village, or area from which it was obtained. This indicates that variety naming within villages is more important than between villages. In The Gambia seed flows mainly within villages and less between villages. Hence, the level of naming consistency between villages can be used as an indicator for the importance and level of seed flow between villages. In Ethiopia for the sorghum farming system to function, farmers need a common variety nomenclature shared by different villages. The naming of sorghum varieties was consistent among farmers from four villages situated along the main highway between Addis Ababa and Woldeya in Ethiopia (Teshome *et al.*, 1997; Tunstall *et al.*, 2001). Of the 48 collected varieties, 35 were grown in at least 3 of the 4 villages (Tunstall *et al.*, 2001). According to Seboka (personal communication), because of irregular rains and frequent failure of the first sowing, it is quite common for farmers to go to farmers in other villages or to markets to find particular varieties, which might explain the greater consistency in name use. Sorghum also has the advantage that the seed quantities needed are small, making travelling easier. In Cuzalape in Mexico where a short and a long growing season exist and seed is exchanged between communities frequently, farmers use a common nomenclature (Louette *et al.*, 1997). In other regions of Mexico, e.g. the region of Oaxaca, maize nomenclature is not consistent between different communities and at the same time the most common seed source is stored seed from the previous harvest (Badstue *et al.*, 2002).

Boundaries of a seed system

After the decrease in rainfall in the 1970s, NGOs, extension and agricultural research played an important role in finding better adapted rice and millet varieties in The Gambia. In the past, before extension services, agricultural research and NGOs existed, farmers must have searched for and found suitable varieties to cope with climatic changes. A question is how important were trade networks, which have declined in importance for rice, in the past in distributing adapted varieties. Another question is how often farmers found adapted varieties through luck. After 1970, farmers in Tujereng found suitable rice varieties relatively easily, while farmers in Janack were not able to find suitable varieties and had to stop rice farming.

Because of farmer exchange, trade and seed distribution by governments and NGOs, it is difficult clearly to define the boundaries of a seed system. Because of farmer exchange with farmers in Senegal (and occasionally Guinea Bissau), the boundaries of the seed system are not the boundaries of the state. A more suitable way to define the boundaries of a seed system is to follow differences in ecological conditions and variety use. For millet, it can be argued that two seed systems exist in The Gambia, one for late millet and one for early millet and that each system spreads across into Senegal. For rice, it is more complex, because different ecologies are not clearly separated in a geographical way, but can be found in many parts of the country, often adjacently. The same varieties are grown in different villages in varying ratios, which makes the situation more complex. Based on variety naming it could be argued that a village in itself forms a subsystem of a wider seed system. In some situations, however, it might be less clear to see a village as a subsystem. A question which is difficult to answer is whether in the past, when infrastructure and transport was less developed, villages were more often systems in themselves and whether nowadays villages are more connected to each other. Gamble (1955) mentions that in the village of Kerewan (North Bank Division) people only found out about a neighbouring village when they saw a bird dropping rice seed.

It might also be possible that over a period of long ecological and socio-economic stability, subsystems become bigger through seed exchange. The question is whether in the future the farmers' variety portfolios in neighbouring villages will become more similar or not. Knowing which varieties were cultivated in the past might help answer that question. Not only improved seed exchange, but also improved extension and seed distribution of the formal sector can probably have homogenising effects on farmers' variety portfolios. This has also happened for various crops in industrialised countries (Jongerden and Ruivenkamp, 1996; Smale, 1997). One can expect that the bigger the subsystems and the more seed exchange between communities, the less genetic diversity becomes available in a seed system, because farmers in different parts of the seed system use the same varieties and each farmer has a limited variety portfolio.

6.6 Conclusions

The following conclusions can be drawn:

- For rice, seed flow within villages is mostly for seed replacement, while seed flow between villages is mostly for exchanging new varieties. For millet, seed flow within and between villages is primarily for seed replacement and hardly any variety testing of millet occurs.
- These differences are related to the number of rice and millet varieties that circulate and, hence, indirectly to the different breeding systems of the two crops.
- It is not possible to conclude that seed flow within villages is more important than between villages, because seed flow within and between villages is different. Both types of flow are equally important aspects of maintaining farmers' access to varieties.
- Farmers acquire seed primarily through the informal sector. Relationships among women are an important channel for rice seed flow between villages. For millet, another seed source is the market where farmers buy grain which they use as seed.
- For rice, the formal seed sector includes NGOs and government departments while, for millet, the formal seed sector is non-existent.
- Variety naming provides information about the importance and direction of seed flows between villages, the time a variety has been in a village, and the person who introduced or developed that variety.
- The names of common rice varieties change over time. Younger names tend to link to persons, whereas older-established names relate to morphology or function.
- Because more rice varieties exist, variety naming is more important for rice than for millet.
- Name consistency is particularly important within villages, less between villages.
- Naming consistency for rice is negatively related to the frequency with which farmers lose seed and the frequency with which they acquire new varieties from the formal seed sector.
- Although farmers share the same millet variety within a village, there is no clear name consistency for millet.
- The fact that no millet varieties are named after persons indicates that the development of new millet varieties is a slow process.

7 Pollen flow and off-types

7.1 Introduction

Whereas Chapter 6 dealt with seed exchange as a source of diversity, this chapter deals with cross-pollination within species as a source of diversity. One might expect that cross-pollination is a more important source of diversity for millet than for rice. The cross-pollination rate for rice is only about 0.5% (Grist, 1986; Purseglove, 1985), somewhat higher for the *japonica* subspecies than for the *indica* subspecies (see Oka, 1988), while for millet, it ranges between 70 and 80% (Burton, 1974; Rao *et al.*, 1949). However, in addition to being a creative force, pollen flow can also be a constraining force in evolution (Slatkin, 1987) and this applies also to crop varieties in farmers' fields. If there is a lot of cross-pollination, new 'better' genotypes hybridise and segregate and cannot maintain themselves in a population. This could explain why there are several accounts of farmers developing new varieties of rice (Richards, 1986; 1996a; Lambert, 1985, Bertuso *et al.*, 2005), but there are no accounts on millet.

Because of the clustering of rice fields and the cultivation of many different varieties in their fields in Sierra Leone, farmers unconsciously promote the chances of cross-pollination between varieties (Richards, 1996a). In Ethiopia farmers minimise the chances of cross-pollination by planting different sorghum landraces at different times and in separate fields (Teshome *et al.*, 1999). In certain areas in Mexico intensive cultivation does not permit all farmers to isolate their fields to prevent cross-pollination (Bellon and Brush, 1994).

It has been stated that gene flow plays a crucial role in the development and maintenance of landraces. However, little measured evidence has been offered of the actual gene flow processes at work in farmers' fields. This chapter shows that, even though cross-pollination in rice is very low, there are possibilities for the emergence of new varieties and genetic variation in rice, whereas this is less likely to happen in millet. Because millet is an outbreeder and varieties show a wide intravarietal diversity, new genotypes are not discovered so easily by farmers and of the few that are discovered is often their fate to segregate and disappear again in the gene pool. If two rice varieties cross-pollinate, a new genotype can develop which does not lose its characteristics through continuous cross-pollination. Further, the chapter seeks to explain farmers' concepts and explanations of variation in rice and millet. The extent to which these are culturally based and related to particular crop features will be discussed.

7.2 Materials and methods

The flowering periods of different rice plots were observed in detail in three upland areas in Tujereng in 2000 (Figure 3.3). In each area 9 or 10 adjacent rice fields were mapped to estimate the possibility of cross-pollination (two areas were partially mapped, while one was mapped completely). Mapping was done with a compass and a tape line. For the calculation of the areas the DOS-based computer program Basica was used. The level of flowering was measured for each separate plot twice a week. Also some basic agronomic features were recorded, such as stand of the field, visual uniformity, date of weeding and date of harvesting. In contrast to rice, millet fields are scattered all over the village and for this reason 11 fields were mapped (Figure 3.3). Although in all fields, except one, the same variety was grown, the question remained whether these fields were isolated in time and/or space. The millet fields were selected at random out of the first 20 compounds who were interviewed. The millet fields were monitored on a weekly basis.

To compare rice genetic diversity between villages (which will be discussed in Chapter 10), 100 samples of 300-400 panicles each were collected from farmers in 4 villages (Faraba, Janack, Kitti and Tujereng). Each sample weighed half a kilo and consisted of 1.5 *bulu* (bunch of panicles that can be held with one hand). Of these 100 samples, 90 samples were considered representative of the variation in farmers' fields because farmers had not applied any selection on these *bulu*. The mixed-in panicles (indicated as other varieties by women) were removed and analysed to assess possible differences in quantity, number and type of mix-ins between seed lots, farmers' fields and villages. For millet, this was not possible, because many men said that there are no mixtures in their variety of millet. And even though some men did give a description of millet varieties, it was not possible to get a consistent account. For rice, this lack of clarity affected only one variety, which comprised of different types.

Much of the information obtained from farmers in this chapter is based on informal interviews and field walks in the villages of Tujereng, Faraba, Kitti and Janack. Some data derive from the questionnaire conducted in 2002.

7.3 Results

Influences of cultivation practices on pollen flow

Rice

As was mentioned in Chapter 3, rice fields can be found in clusters. In the lowlands, space is often limited, 'forcing' farmers to situate their fields adjacent to each other. In the uplands, clustering of rice fields has the advantages of easier clearing and burning, and reducing pest damage. Figure 7.1 shows the flowering patterns of three upland rice areas in Tujereng, as observed in 2000.

- The fields in area 1 are mostly cultivated by women who belong to the founding families. Most of them do not have a husband able to clear the land (either the husband died, is ill or is old) and all of them work on 'second year' *tandako* (*tandako* that is used for the second year), which has the disadvantage that it is very weedy. In area 1 fields are small and many different varieties are grown.

- The fields in area 2 are mostly cultivated by women who do not belong to the founding families and who also do not have a husband to clear land for them. Before rainfall declined, this area was shallow lowland and cultivated every year. Because of continuous cultivation, the area is relatively easy to clear by the women themselves. However, weeds are abundant and soil fertility is lower than in areas 1 and 3, because of continuous cultivation. Fields are quite small, and fewer varieties are grown compared to area 1.

- The fields in area 3 are cultivated by women who do not belong to the founding families and who do have a husband to clear the land for them. Fields are relatively big, and only the common varieties are grown in this area.

Flowering is most uniform in area 3 and least uniform in area 2. Possibly the main reasons for the highest uniformity in flowering in area 3 is that all varieties have a similar time of flowering (# days between sowing and flowering) and are planted at the same time. Area 2, where fewer varieties are sown than in area 1, shows the greatest variation in flowering, probably the result of differences in sowing dates and differences in weeding. Except the variety Bonti, none of the varieties grown in these 3 areas (listed in Table 7.1) are photo-periodic sensitive (based on data not shown).

Table 7.1: List of varieties shown in Figure 7.1.

A = Kari Saba	H = Hombo Wulengo	O = Bonti
B = Binta Sambou	J = Jokadou Mano	R = Sainy Kolly
C = Sefa Koyo	K = Kukur	S = Sonna Mano
E = Bendou	M = Mani Mesengo	V = Foni Mano
F = Sefa Fingo	N = Sefa Nunfingo	W = Mani Wulendingo

In Tujereng women try to sow rice as early as possible (particularly in the uplands), but the actual planting date is determined by various practical factors. One factor is the time of clearing of the fields (in the uplands done by men). Another factor is the labour available. Some plots and/or fields are sown or planted piece by piece by one person, while other plots and/or fields are sown or planted in one day by a *kafo* (work group, see Chapter 2), resulting in mosaics with plots of different sizes and sowing dates. Between plots paths are not sown (in the uplands this is to enable bird scaring) but sometimes these paths are very narrow, even to the extent that sometimes it is difficult to see where one plot ends and the other starts.

In the lowlands the same woman usually works the same plot every year, although it also happens that a woman might lend her field, or part of her field, to another woman. In the uplands rice field locations are very dynamic: Every year, before the season starts, women will find out from each other who wants to grow rice where, and each year it happens that groups change and different women are working together in different groups. Some women, however, prefer to work together every year. Groupings are usually based on friendship and kinship within the village.

In the uplands women sometimes use varieties of different duration, often sowing the long duration varieties first and the short duration varieties second. The long duration varieties are 'old' farmer varieties preferred because of their good taste, which do not really fit the shorter rainy season anymore. For this reason they are often planted first to catch whatever rain they can. Usually, these varieties are sown in small plots, while the well-adapted 'common' varieties are sown in much bigger plots. Unlike the long duration varieties, the common varieties are sometimes sown piece by piece and flower at different periods. Because of the variation in flowering periods of the common varieties, and because the 'old' farmer varieties are sown first, the common and 'old' farmer varieties at times flower simultaneously (Figure 7.1).

Proximity of plots and coincidence of flowering create possibilities for cross-pollination between plots with different varieties. However, because rice is an inbreeder, chances of cross-pollination are low. Moreover, the furthest distance over which cross-pollination in rice can take place is between 1.5 and 2.1 m (Srinivasan and Subramanian, 1961; Reano and Pham, 1998). The harvesting of seed by farmers allows some products of cross-pollination to germinate and flower in the next season. When farmers select seed, they tend to harvest it from a good part of the field, irrespective of whether it is close to the border or not (see Chapter 4).

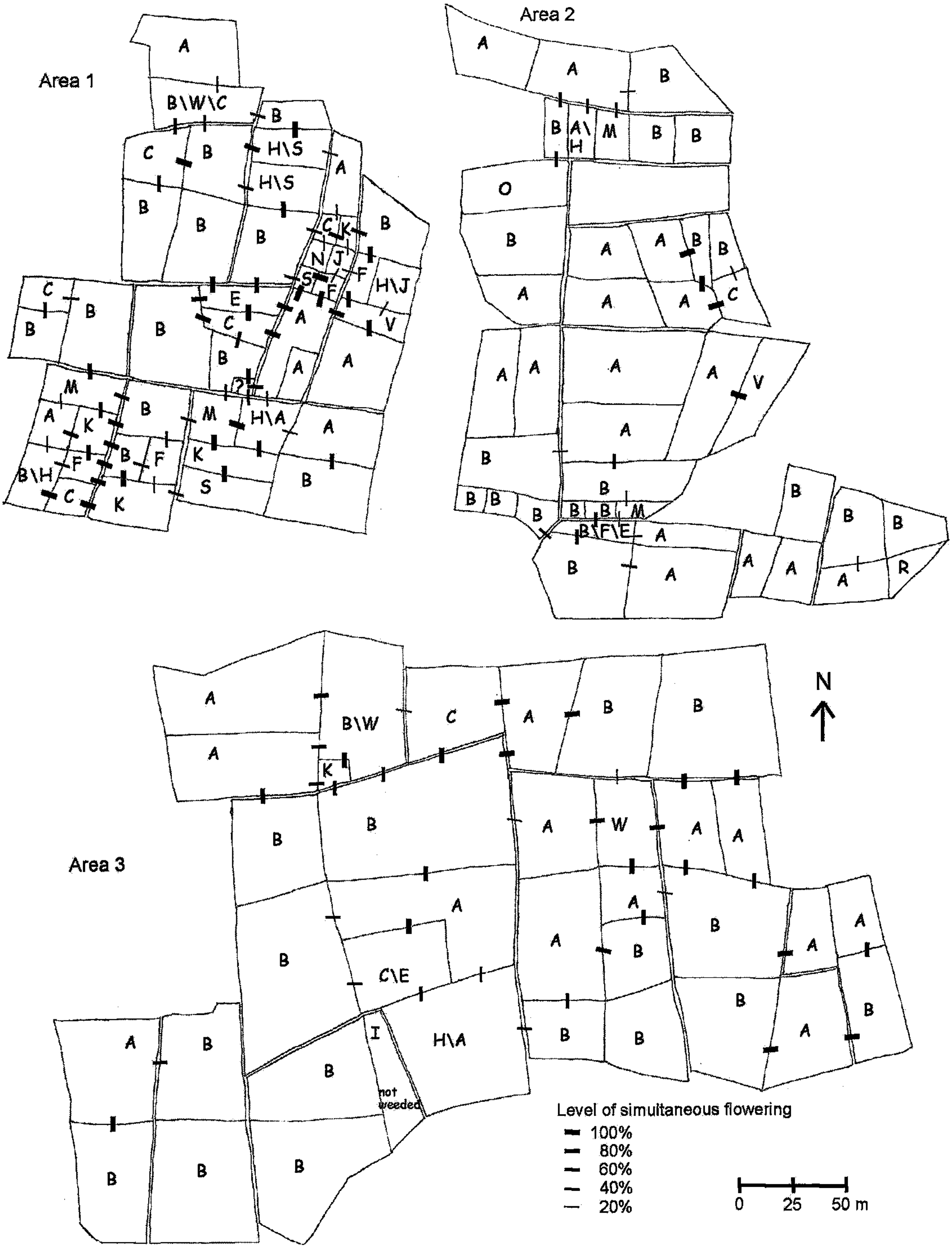


Figure 7.1: Flowering periods of rice varieties in Areas 1, 2 and 3 in 2000. The underlined letters indicate the varieties grown (for full names see Table 7.1). The short lines across plot boundaries indicate the co-incidence of flowering between plots. Boundaries between fields are indicated with double lines and boundaries between plots are indicated with single lines.

Millet

The sowing dates of millet fields differ in Tujereng, depending on the availability of oxen for the ploughing (ploughing of millet fields is more common in Tujereng than in other villages, see Chapter 3). Furthermore, soil fertility and time and frequency of weeding also influence plant development and thus the time of flowering. However, because of the photo-periodic farming practices causes a millet field to flower at a different time than other millet fields. In Tujereng there is one farmer who sows his field much later, and the flowering of his field does not coincide with the flowering of other fields. The reason he sows his millet later is that he learned to do so from his father, who originates from South West Casamance, where the rainy season is longer. In that area millet performs better if sown late.

Some fields are next to each other, while other fields are rather isolated (Figure 3.3). The locations of the fields change every few years (particularly those worked by strangers who do not own land), and in that way different fields of different farmers can become linked to each other at various points in time. Since millet field can be situated anywhere in Tujereng, they can also be closely located to millet fields of other villages. Hence, millet gene pools of various villages are connected through pollen flow between their fields. The more densely populated an area is and the smaller the distances between villages, the more likely that millet fields of neighbouring villages are situated next to each other.

The guidelines for millet seed production indicate that, to prevent cross-pollination between fields, the isolation distance should be at minimum 400 m (Gupta, 1999). This suggests that gene flow is possible between distant fields. However, under experimental conditions, the rate of cross-pollination was 3.7% at a distance of 1 m and only 0.02% at a distance of 55 m (Burton, 1974). It is possible that because of the set-up of the experiments these rates of cross-pollination are somewhat underestimated, but they do indicate that effective cross-pollination over longer distances is very limited. Insects are another common vector of cross-pollination in millet, but it is unclear over what distances cross-pollination by insects is effective (Leuck and Burton, 1966). Similar percentages were found for maize. In maize, cross-pollination at the borders with neighbouring fields is considerable (up to 60%), but rates 15 m away from the border are very low (Gonzalez and Goodman, 1996). In another study on maize, cross-pollination rates between fields decreased from 10 to 20% in the first row to 1% after 2 to 3 m (Louette, 1999). For many other crops, distances greater than 15 m may effectively isolate plant populations (Ehrlich and Raven, 1969). This does not mean that no pollen flow occurs between fields at distances larger than 15 m from each other, but that the effect of pollen flow between fields will be very small in relation to that of pollen flow within a field. So, although theoretically, gene flow through pollen is possible between villages, the rate of this gene flow is likely to be negligible.

One might be quick to relate the differences in location of rice and millet fields to gender and to women being more co-operative than men, but there are several reasons to assume that gender plays a less important role than environmental conditions and crop-specific factors. The rice lowlands are often scarce, so women are forced together in the same area, whereas upland fields suitable for millet cultivation are often in abundance. Whereas millet is grown in non-bush areas, upland rice is grown in or near a forest, where, apart from birds, other pests like monkeys and rabbits are common. To reduce the border area with the forest, women prefer to cluster their fields as much as possible. In the case of watermelon, grown by men, the fields are also clustered to reduce damage by monkeys and other pests.

Mixtures and off-types

Rice

Through careful observation of rice fields one can see differences in the level of mixtures and off-types between fields. First, the nature and causes of off-types will be discussed. After that, the chances of cross-pollination within and between fields will be discussed. Of 90 samples (300-400 panicles each) all 'off-type' panicles were removed, based on farmers' directions. The 'off-type' panicles were analysed to assess possible origin and differences in quantity between varieties, farmers' fields and villages. The term 'off-types' refers to panicles that were either i) currently grown varieties in the same or other villages ('mix-ins'), ii) old disappeared varieties, iii) unidentifiable genotypes of *O. sativa*, or iv) unidentifiable genotypes of *O. glaberrima.* Majority of the mix-ins were other varieties grown in the same village. A few 'off types' were *O. glaberrima* material (6%) and a few (± 2%) were old disappeared *O. sativa* varieties. A number of panicles (±3%) could not be identified, of which a part (±0.4% of all off-types) segregated when sown and thus are products of cross-pollination.

Although farmers remove off-type panicles from their sowing seed, still, many off-types can be observed in the fields (see also Chapter 4 on seed selection). The number and quantity of off-types varies between fields, related to differences in farmer seed selection (which is primarily aimed at varietal purity). Some women have a greater interest in seed selection and variety management than others. Older women have more experience than the younger, and often the first wife (normally the oldest) takes the lead in rice farming and knows more than the others (if the wives of one husband work together).

The number and quantity of off-types also varies between plots (each field is divided in plots, separated by walkways to enable bird scaring) because of the different varieties grown in those plots. Because the morphological distinctiveness varies between varieties, it is easier to keep certain varieties pure than others. For example, in a variety with a red husk, it is easier to observe off-types with a white husk colour than with a similar red husk colour. Moreover, only a few varieties exist with a red husk. In one plot (with a variety called *Sefa Fingo*) only 1 off-type could be found, while in another plot (with a variety called *Jokadu Mano*) 11 different varieties of rice could be found (9 *O. sativa* varieties and 2 *O. glaberrima* varieties). Because of the distinctive husk colour of the variety *Sefa Fingo*, hardly any off-types are found in this variety.

Not only the number and quantity of off-types differs per variety, but in each variety a different set of off-types can be found. In a variety with a red husk, *Hombo Wulengo*, some old 'lost' varieties were still present. According to farmers, *Hombo Wulengo* needs to be sown as a mixture (see Chapter 5), which might explain why it contains so many off-types. Another off-type (without name) was mostly present in the variety *Sefa Koyo* (Appendix 7). The variety *Sefa Koyo* in turn was mostly found as an off-type in the varieties *Kari Saba* and *Binta Sambou.*

Off-types can also differ between villages. Most mix-ins found in Tujereng are varieties grown in Tujereng. However, in Tujereng some mix-ins were found that could be identified as varieties planted in the other villages, but not in Tujereng itself. The mix-ins found in the villages Janack, Kitti and Faraba are mostly different from those in Tujereng (Appendix 8). The variety *Binta Sambou*, grown in Tujereng, Kitti and Faraba, has different mix-ins in the different villages. In Tujereng the variety *Sefa Koyo* is a common mix-in in the variety *Binta Sambou*, while in Kitti and Faraba *Peking* is the common mix-in. Since the variety *Kari Saba* is quite common in all villages, it is also logical to be regularly found as a mix-in. However, *Sonna Mano*, only grown in Tujereng by a few people, can also be found as a mix-in in the other villages, mostly in short-stature formal varieties. *Tombong mano*, grown by one farmer in Janack, can also be found as a mix-in in all villages. *Bendou,* a long duration variety and rarely grown, is often found as a mix-in in many different varieties in all villages. But *Kukur* and *Hombo Wulengo* are grown rarely and not often found as a mix-in.

It can be concluded that each village not only has a distinct set of varieties, but also a distinct set of off-types (Appendix 8). Also, some varieties, though rarely grown, are found as a common mix-in, while other rarely grown varieties are hardly found as a mix-in in other varieties. Some varieties can survive more easily as a mix-in, while other varieties eventually will disappear. The latter have in common that they need a long rainy season to survive. Another reason why some varieties are not common as a mix-in is that they have a very distinct husk colour and are easily rogued. However, some varieties with 'common' duration and non-distinct husk colour are not common as a mix-in in other varieties. Apparently, the ability of varieties to remain as a mix-in in the sowing seed of other varieties varies. Possibly, *japonica* varieties have a lower competitive ability than *indica* varieties.

Furthermore, quantities of off-types differed between villages. Samples from Tujereng and Kitti contained more off-types than samples from the other villages (Table 7.2). The average number of off-types found in the samples from Kitti is higher than those from the other villages (Table 7.3). Also, the 13 samples from Kitti contained as many different off-types as the 44 samples from Tujereng. It is difficult to give a good explanation for these differences.

Table 7.2: Differences in quantity of off-types found in rice samples collected in four villages in 2000.

quantity (# panicles / sample)	quantity (% of sample)	Tujereng	Kitti	Faraba	Janack	total
total # samples		44	12	16	18	90
0-10	< 3 %	9	5	7	10	31
11-25	< 7.5 %	11	2	7	4	24
26-50	< 15 %	3	1	0	4	8
51-100	< 30 %	14	3	1	0	18
101-	> 30 %	7	1	1	0	9
average		14.9	10.8	6.4	4.4	10.7

[1] = given an average cross-pollination rate of 0.5%, and random distribution of off-types in the field

Table 7.3: Total number, average number and range of off-types in rice samples collected in four villages in 2000.

village	# samples	total # off-types	# off-types / sample		std. deviation	minimum	maximum
Tujereng	44	29	4.1	ab	2.26	0	11
Kitti	12	29	5.6	b	2.23	1	9
Faraba	16	20	3.2	a	1.60	1	6
Janack	18	18	2.7	a	1.71	0	5
total	90	38[1]	3.9		2.18	0	11

[1] = The total is not equal to the sum of the villages

Millet

For millet, many farmers at first said they did not have off-types in their field. Later on, they did say they have some off-types, but could not clearly describe which plants belong to their variety, and which are off-types. Hence, it was not possible to do a similar exercise for millet. The remark 'millet is millet' was often used by farmers during interviews. Many farmers perform some kind of selection (see Chapter 4) to obtain good quality sowing seed, but also to keep the right characteristics in their variety. In Foni, where all farmers grow *white sanyo*, sowing seed contains fewer black grains than the *white sanyo* grown in Kombo, where many farmers grow *black sanyo* instead of white. Most *black sanyo* grown in Kombo also often contained a small percentage of white grains.

Cross-pollination between and within fields

Estimates of cross-pollination rates in rice

These estimations were calculated as follows. The average cross-pollination rate in rice is generally assumed to be about 0.5% (Purseglove, 1985; Grist; 1986). Studies conducted by Roberts *et al.* (1961) and Reano and Pham (1998) yielded percentages of 0.56% and 0.5%, respectively. In these two studies, the trials consisted of two varieties in an equal ratio, of which the plants were spaced at an equal distance from each other. The experiment conducted by Brown (1957) consisted of ¾ of male plants and ¼ of female plants. When adjusted to the plant ratio used by Roberts *et al.* (1961), the cross-pollination rate found by Brown is about 0.55%. The study conducted by Lord (1932) suggest a similar rate, but when adjusting to the methodology used by Roberts *et al.* (1961), the cross-pollination rate found by Lord is about 0.75%, within the range of percentages found in the other studies mentioned above. The highest percentage found among the above studies was 1.59% by Brown (1957). Oka (1988) suggests that cross-pollination rates up to 6.8% occur in rice.

A rate of 0.5% based on an alternate stand of two varieties corresponds quite well with the cross-pollination rate between plots found by Srinivasan and Subramanian (1961). The average rate they found is only 0.035% over a distance of 3 m. However, whereas the rate calculated by Roberts *et al.* (1961) is based on pollen flow between two varieties (2 ways), the rate found by Srinivasan and Subramanian (1961) refers to the pollination of one variety by the other (1 way). Whereas in the study of Roberts *et al.* (1961) the two varieties can pollinate each other in all directions, in the study of Srinivasan and Subramanian (1961) the pollen of one variety can only reach the other variety in one direction, reducing the chances of pollination by at least a factor 3. Further, whereas the rate of 0.035% is calculated based on a distance of 3 m, Srinivasan and Subramanian (1961) did not find any cross-pollination over a distance greater than 2.1 m and their data suggest an average maximum pollination distance of 1.3 m. Reano and Pham (1998) found no cross-pollination over a distance of 1.5 m. Dividing a rate of 0.5% by 2 (pollen flow from one variety to the other but not vice versa), 3 (pollen flow in one direction) and 2 (assuming a maximum pollination distance of 1.5 instead of 3 m) gives a rate of 0.042%, only slightly higher than the rate of 0.035% found by Srinivasan and Subramanian (1961). This means that the rate of 0.5% for cross-pollination within plots corresponds to the rate of 0.035% for cross-pollination between plots.

Level of cross-pollination within rice plots

For the estimation of the rate of cross-pollination within a plot between plants of a variety and off-types the following formula is used: $(A * B * C * D * E) + (A * B * C * D * E)$, in which the first multiplication of factors estimates the flow of pollen from the variety to the off-type plants and the second multiplication estimates the flow of pollen from the off-type plants to the variety. In this calculation the factors A, B, C, D and E represent:

A) The percentage of 'off-type' pollen of the total of pollen from plants of the off-types and of the variety reaching the stamens of the variety and vice versa.
B) The percentages of plants of a variety and of the off-types in a field.
C) The distance between plants of a variety and the off-types in a field. This factor seems to matter only when the percentage of off-types in the field is less than 10%. The area of a field, as a percentage, was estimated where cross-pollination between plants of a variety and

the off-types is unlikely to happen. This percentage is subtracted from 1, yielding the value for C.

D) The average one way crossing rate in rice of 0.25%.

E) A correction factor for the formula to yield the percentage of 0.5% obtained by Roberts *et al.* (1961) as they did not use variables A and B in their calculations.

Table 7.4 shows estimations of the level of cross-pollination within plots between a variety and the off-types in relation to the quantity of off-types found in the rice samples. Table 7.4 also includes the calculation of the cross-pollination rate found by Roberts *et al.* (1961).

Table 7.4: Estimations of cross-pollination rates in rice fields with various levels of off-types.

quantity (# panicles per sample)	average quantity off-types (in % of sample)	A * B * C * D * E (from variety to off-type)		A * B * C * D * E (from off-type to variety)		rate of cross-pollination variety – off-type
Roberts *et al.* (1961)	50	0.5 * 0.5 * 1 * 0.25 * 4	+	0.5 * 0.5 * 1 * 0.25 * 4	=	0.5%
0-10	1.5	0.985 * 0.015 * 0.34 * 0.25 * 4	+	0.015 * 0.985 * 0.34 * 0.25 * 4	=	0.01%
11-25	5	0.95 * 0.05 * 0.61 * 0.25 * 4	+	0.05 * 0.95 * 0.61 * 0.25 * 4	=	0.06%
26-50	11	0.89 * 0.11 * 0.94 * 0.25 * 4	+	0.11 * 0.89 * 0.94 * 0.25 * 4	=	0.19%
51-100	22	0.78 * 0.22 * 1 * 0.25 * 4	+	0.22 * 0.78 * 1 * 0.25 * 4	=	0.34%
101-	35	0.65 * 0.35 * 1 * 0.25 * 4	+	0.35 * 0.65 * 1 * 0.25 * 4	=	0.46%

Applying the above formula on the samples shown in Table 7.2 yields the cross-pollination rates shown in Table 7.5. The average percentage of off-types over all samples is 10.7% (Table 7.2). The average over the village averages is only 9.1%. The second percentage is lower than the first because the sample number from Tujereng is much higher than from the other three villages. The average cross-pollination rate between a variety and off-types growing in the same field across the villages is 0.125%, based on the average village percentages of off-types. The rate ranges from 0% to 0.46%, the latter being close to the average cross-pollination rate in rice.

Table 7.5: Average cross - pollination rate between a variety and off-types in rice fields, estimated for samples collected in 4 villages.

	Tujereng	Kitti	Faraba	Janack	total
total # samples	44	12	16	18	90
average percentage of off-types in samples	14.9	10.8	6.4	4.4	9.1
average cross - pollination rate between variety and off-types[1)]	0.21	0.15	0.08	0.06	0.13

[1)] using the formula shown in Table 7.4

This implies that sowing seed will contain on average 0.125% of seed produced through cross-pollination (ranging from 0% up to 0.46%). This means that from every 10,000 seeds, we can expect 12.5 seeds to be hybrids. These numbers are small, but not insignificant. The average farmer in the study area sows ± 0.9 ha for which she needs 40 kg of sowing seed. Given that 100 seeds weigh 2.5 grams, 40 kg contains 1.6 million seeds, of which 2000 will be hybrids. To obtain that quantity she needs to harvest an area of about 400 m^2, which contains ± 12.000 plants, of which up to 55 plants will be the product of hybridisation. Depending on the skill of the farmer, these hybrid plants will be either harvested for seed, rogued or missed and eaten.

Usually, varieties with a distinct husk colour and shape contain fewer mixtures, and chances of cross-pollination are smaller, whereas varieties with a non-distinct husk colour and shape contain more off-types (also with non-distinct husk colour), and chances for cross-pollination are higher. However, in the latter case, products of cross-pollination can often go unnoticed because they also inherit the non-distinct husk colour and shape of their parents.

Level of cross-pollination between rice plots

For those fields and plots of which the flowering period was recorded, the chances of cross-pollination between different varieties in neighbouring fields were calculated for each of the 3 areas described earlier (see Figure 7.1). The average cross-pollination rate between plots over a distance of 3 m found by Srinivasan and Subramanian (1961) was 0.035%. This rate is used in the formula below. The path between plots is about 0.5 m wide. Hence a distance of 2.75 m instead of 3 m is used for the calculation of the area where cross-pollination is possible. A problem is that the rate of cross-pollination decreases exponentially over distance, which means that the chances of cross-pollination in the area subtracted for the path (0.25 m) are much higher than 1 m away from the border. The calculations below are thus a slight overestimation of the chances of cross-pollination between plots.

Per plot, the rate of cross-pollination with neighbouring plots was calculated as follows:

> Total area of a plot where cross-pollination with different varieties in neighbouring plots is possible * level of overlap in flowering between fields * Average cross-pollination rate of rice / Total plot area

Per area the average cross-pollination rate is calculated over all plots. The average cross-pollination rate between different varieties in neighbouring fields is 0.005% (Table 7.6). The average in area 1 is much higher than in areas 2 and 3. The higher pollination rate in area 1 is caused by the high number of varieties sown in that area. In area 2 the rate is lowest because in many neighbouring fields the same varieties are sown and different varieties grown in neighbouring plots differ in flowering period, either caused by differences in growth period or through different sowing dates. The low rate in area 3 is caused by the low number of varieties sown and by the large plot sizes.

Table 7.6: Average percentages of cross-pollination in rice at plot level between neighbouring plots with different varieties if 0.035% is assumed as the average cross-pollination rate over a distance of 3 meter, calculated for 3 upland rice areas in Tujereng.

	# plots	pollination rate	range
area 1	24	0.009	0.001 - 0.023
area 2	19	0.002	0.000 - 0.006
area 3	26	0.003	0.000 - 0.009
total	69	0.005	

The average cross-pollination rate between different varieties in neighbouring fields is 25 times lower than the average cross-pollination rate between varieties within fields, being 0.125%. Both values represent cross-pollination rates at field level. This means that new genotypes develop more likely through cross-pollination between varieties within fields than between fields.

This comparison is partly based on data from Tujereng. The average area per variety is larger in most other villages (Table 5.1). This means that the difference in cross-pollination between plots and within plots is likely to be larger in other villages. Even if the level of off-types is lower in other villages, comparable to the level of off-types found in the samples from Janack, the level of cross-pollination within fields is still 12 times higher than between plots. From this information it can also be understood that in villages with common varieties (see Chapter 6) the level of cross-pollination between fields will be lower than in villages where no common varieties can be identified and at village level farmers grow a larger number of varieties.

Level of cross-pollination in and between millet fields

Because the exact percentages of off-types are not known, it is not possible to give estimations like is done for rice. As the seed samples collected in Kombo contained more off-types than the samples from Foni, cross-pollination between varieties is more likely to occur in Kombo than in Foni. Furthermore, it is likely that, given the exponential decrease in pollination rates over distance (Burton, 1974), cross-pollination occurs more readily within fields than between fields. This is similar to the findings in rice.

Farmers perceptions about off-types

As part of the 2002 questionnaire, farmers were asked whether they have any off-types in their field. For both millet and rice, a similar percentage (70%) of men and women said they do (Table 7.7). For both millet and rice, there are no differences between ethnicities and districts. For millet, there are also no differences between ecologies. For rice, all women who broadcast and transplant rice said they see off-types in their field. This is probably due to the fact that they handle more varieties and that early and late maturing varieties get mixed up and, consequently, are noticed quicker because of differences in flowering.

Table 7.7: Percentages of men and women who see off-types in different ecologies of millet and rice respectively; N = 122 for millet and N = 132 for rice (data from 2002-questionnaire).

	millet				rice					
	suno	*sanyo*	*majo*	total	*tandako*	fs *faro*[1]	fs+p *faro*	fp *faro*	fm *faro*	total
does not observe off-types	30	30	35	31	17	37	0	44	33	29
observes off-types	70	70	65	69	83	63	100	56	67	71

1) fs *faro* = farmers who boadcast rice; fs+p *faro* = farmers who sow and transplant rice; fp *faro* = farmers who transplant rice; fm *faro* = farmers who transplant rice in associated mangrove lowland

For millet, some men said the off-types they find in their fields are mix-ins of early millet or sorghum in late millet. These answers can be clarified by reference to farmers' nomenclature for millet and sorghum (See Chapter 6), which explains the rather high percentage of farmers observing off-types. Others said they never see any off-types in their field, because in the wider area only one variety is grown. One man also said that he selects his seeds and stores them in a container, so there cannot be any mixture.

A majority of women think that off-types in rice are caused by run-off water, while some women think that off-types are caused by mix-ups during storage or threshing or claim not to know. Explanations given by only a few women are God, birds, animals, the devil and improper selection.

The most common explanations for the occurrence of off-types in millet, given by men, are seed mixtures, ants, birds, God, and run-off water. Some men said they do not have any idea. Less common explanations are: disease, improper selection, continuous cultivation in the same field, and low soil fertility. After sowing, it is very common for ants to carry the seeds away and for birds to eat them. These explanations are related to recurrent events in millet fields. But even if ants and run-off water carry away millet seed, the seed will likely end up in a field with the same millet variety. Run-off water also seems somewhat an illogical explanation for off-types in millet because of the flatness of the country, but is maybe mentioned because it is a common explanation of women for mixtures in rice.

In general, women do not really mind to have off-types growing in the field, as long as they are few. MS, in whose field *Sefa Koyo* (an 'old' farmer variety) was growing as a mix-in, said it is good if you can still find this variety in your field. In former years there was more rainfall and it was possible to grow those varieties (*Sefa Koyo*, *Sefa Fingo*, *Mani Tima*), whereas now, only a few farmers are growing those 'old' varieties, because the rainfall is not sufficient. So, it is good if you find *Sefa Koyo* in your field if you did not sow it, it is natural. It is even possible to sow a handful of *Sefa Koyo*, just to have it in the field. YM said it is good to find mixtures in your field, so that you have the choice to harvest it separately and cultivate it the next year. FT said you always find mixtures of varieties in your field, even if you do careful selection of the sowing seed. Another woman said that trying to rogue the off-types is a waste of time. Some of the older women purposefully mix a little bit of *O. glaberrima* in their seed, out of respect, because it is the oldest rice (see Chapter 5).

Farmers perceptions about strange off-types

'Strange off-types' are plants that cannot be classified as mix-ins, nor as *O. glaberrima* (in the case of rice) or early millet (in the case of millet). These strange varieties are either unfamiliar existing varieties or 'new' off-types resulting from cross-pollination.

<u>Rice</u>

When woman are asked whether they see any strange off-types in their fields, most said they only see mix-ins (other common varieties) in their field, but some women said they see both mix-ins and strange off-types in their field. Most of those reporting strange off-types say they are caused by God or Nature. A few women mentioned heavy rain. Most women said they would thresh and eat strange off-types. Fewer said they would test them in the next season (Table 7.8). One reason women consume these strange off-types instead of testing them is that they do not fit the ecology. AJ said she only sees strange off-types if there is a lot of rainfall. Another reason not to test strange off-types is when the strange off-type does not look impressive. The third and last reason for women not to test strange off-types is lack of time or 'patience' as women call it. PB said that if she has the patience she will harvest a strange off-type with potential separately, but if she does not have the patience she will just consume it.

Some women who said they would test any strange varieties they saw said they had, in fact, never seen any strange varieties before, but they knew it was possible to find strange varieties in rice fields. JJ, aged 50, said the year 2000 was the first year she found a strange variety. PB said about an off-type in Mani Wulendingo I showed her: 'it can always happen that there is a strange rice variety growing in your field; That is how *Masirinding Mano* came about and also *Penkou Mano*' (not grown anymore). According to KB *Sefa Koyo* was also discovered as a strange variety in a field long ago. According to PB and others, any variety called *Sefa*____ is found in a field of *Sefa Fingo*, that is why all these varieties are called *Sefa*____. In Tujereng there is also some controversy about the origin of one variety called *Binta Sambou*: The woman who found it said she found it in her field, while other women said she found it in bags of imported rice: Both are feasible explanations (see Box 5.2). Information in Chapter 10 indicates the first explanation is more likely in this case.

An interesting aspect is that according to these women, none of these strange off-types segregated the next year, which either means that they are varieties from elsewhere, or that several years had passed between the time of hybridisation and discovery to allow fixation of the genotype.

Table 7.8: Number of women who have seen strange off-types in their fields and what they do with them (data from 2000-interviews).

	Tujereng	Kitti	Faraba	Janack	total
does not observe strange off-types	19	4	9	2	34
observes strange off-types	15	5	4	7	31
does not test nor rogue off-types[1]	3	2			5
test off-types	6			2	8
rogue off-types	5	3	4	4	16
test and rogue off-types	1			1	2

[1] rogued panicles are consumed.

Millet

When asking men whether they see any strange off-types (unusual varieties never seen before) in their millet, their first response is often 'Yes, it is possible to see mix-ins' or 'If you sow sorghum, you harvest sorghum, if you sow millet, you harvest millet'. Another common response is '*Sanyo* (late milet) gives *sanyo*, *suno* (early millet) gives *suno*'. Many men said they never saw any strange off-types in millet. KM said he has never seen strange millet plants. He has seen spikes with red seeds, but he does not discard them, because it is also millet. Also in sorghum he has never seen any strange plants. He does not know why rice does change and sorghum and millet do not. One man in Sangajor said that rice has strange off-types, but millet does not have strange off-types. He does not know why rice has strange off-types, but it happens.

After more probing, some men will say they have seen some millet plants they never saw before. None of those farmers said they tested them. A few farmers attribute the strange off-types they see to diseases or soil fertility. In MG's field we also saw a plant flowering very early. MG said it flowered early because it was diseased. However, no disease was visible on the plant and it is more likely the plant was a rare, early flowering off-type. One farmer in Batabut Kantore who grows white millet said that sometimes his millet has a black colour, which he attributes to cow dung.

Other men said that these strange plants have a natural cause. AJ said that there are sometimes plants with red seeds growing in his field. He had never used them for sowing seed and never tested them, since he has no idea what conditions they need. He does know the conditions his own variety needs. Normally the red seeds are eaten. But still, each year, there are some plants in the field with red seeds. He does not know the origin of these plants. OJ said there are plants with shorter or longer spikes, which have fewer bristles. He does not know why, but he knows that cassava also changes, so it may be natural. FS puts it this way: 'There are always plants that look different, even if you do the selection very well: This difference has a natural cause - your children also look different'.

BS said that if you sow white millet, black millet sometimes comes out of it. MJ said the same, and added that also the reverse is true; if you sow black millet, some white millet results. He also said that this was the origin of the rice variety Binta Sambou: it was found in a field of Kari Saba; and Binta Sambou and Kari Saba look alike. He knows that red millet appears in his field every year. Some people, long ago, separated a small bundle of red millet, which eventually they gave to women to be threshed, pounded, and made into *munkoo*[11], which tasted very nice. He once separated red millet intending to sow it, but eventually decided not to. He gave no particular reason for this change of mind. He suggested that the reason no man has ever found a new variety of millet is that men do not have their mind on that, whereas women are keenly interested. For sorghum, it also happens that men see new varieties emerging in the field. If the field is big, you must see several strange plants. These are caused by God. Even if you select your seed carefully, to make sure that there are no off-types in your seed, you will still find different plants in the field. He has never heard of men selecting strange sorghum plants for sowing. AJ-2 also sometimes sees spikes with dark brown seeds, which he harvests together with the rest of the field. He does not keep them apart and does not test them. He said he has never heard of men selecting a new variety of millet. Men never did that, finding new varieties is something done by women. Women are naturally more curious than men, he believes.

A different explanation was given by MJ-2, supported by a few other men. MJ-2 claimed that men never selected any new variety of millet or sorghum because they are too busy in the field and lack time to harvest strange plants separately, whereas women have more time to harvest strange plants separately. This seems a somewhat strange comment, given the fact that, in general, women are far busier than men. What is different is the process of harvesting. A millet field is harvested by a few older men and many boys who harvest a field in a couple of days, while a rice field is harvested by a few women a piece at a time and they may take a couple of weeks to complete the work. Usually, boys (or youths) are inexperienced in farming, and have little eye for differentiating off-types. Furthermore, before the actual harvest, all millet plants are knocked over to the ground, to make the cutting of the millet spikes easier. When the millet plants lie on the ground, they make one big jumble of stems, leaves and spikes, making it difficult to observe off-types. But in the case of rice, rice panicles are harvested one by one, making it easier to recognise off-types.

Thus, in summarising, the reasons men do not select and test off-types of millet we should not that millet off-types are lower in frequency than rice off-types, the harvesting process in millet makes the selection of off-types more difficult and men consider themselves incapable to select off-types.

7.4 Discussion

The data presented in this chapter show how farming practices affect mixtures of varieties in the field and the chances of gene flow within and between fields. It is clear that these factors function differently in rice and millet cultivation. It is important at this point to discuss these findings in a wider, comparative context.

Influence of farmer practices on pollen flow

As explained in Chapters 3 and 5, in The Gambia the farming practices and variety management of rice and millet differ. Farming practices for rice are more likely to promote pollen flow between different varieties, particularly within fields, when compared to millet. Although chances for cross-pollination in rice are low, field lay-out and farming practices tend to enhance whatever chances are available. If women grow several rice varieties of different duration, they often sow the late maturing varieties first and the early maturing varieties later, resulting in simultaneous flowering. Very often, rice seed is not pure and up to one third may consist of off-types. Particular varieties are sown mixed and, for experimentation, varieties are

[11] Dough made of either millet or rice flour and water

often sown in a mixed stand. It has been shown that, as a consequence, chances for genetic recombination are much higher within fields than between fields.

By comparison, millet fields are not clustered and because cross-pollination rates at distances greater than 20 m are negligible (Burton, 1974; Ehrlich and Raven, 1969), the likelihood of cross-pollination between fields is negligible, even though millet is more of a natural outcrosser than rice. In maize, cross-pollination in the borders of neighbouring fields is considerable, up to 60%, but rates 15 m away from the border are very low (Gonzalez and Goodman, 1996). Unlike in Mexico, where each farmer grows several varieties of maize (Louette, 1996, Bellon and Brush, 1994), or in Nigeria where farmers grow several varieties of millet (Busso *et al.*, 2000), in The Gambia almost all farmers in the same village grow the same variety. So, even if there is cross-pollination between fields, there will be mainly exchange of the same genetic information.

Compared to Gambian farmers, maize farmers in Chiapas in Mexico have a much wider sowing window (of up to 6 weeks), which can both increase and decrease chances of cross-pollination between different varieties (Bellon and Brush, 1994). Mexican maize farmers, however, do not seek to isolate different varieties (Louette, 1996). The wider sowing window enables farmers to choose to vary the sowing dates of early and late maturing varieties with the effect that the flowering of varieties with the same duration may not coincide and that the flowering of varieties with different durations may coincide.

In all, it can be seen that effective pollen flow is a function of a number of factors: the rate of cross-pollination, the length and reliability of the rainy season, location of the fields, number of varieties grown per field, number of off-types within fields, growth duration of different varieties and photo-period sensitivity. It so happens that for millet in The Gambia several of these factors tend to be limited.

Mixtures and off-types

Farmers discard off-types from their sowing seed, but are never able to purify their seed completely. Whereas women do have clear descriptions of rice varieties, men do not have clearly defined descriptions of millet varieties. This lack of clarity aligns with the fact that morphological variation in millet is continuous, rather than discontinuous as in rice. This continuous variation in millet is confirmed by molecular analysis (Chapter 10). As a consequence, it is more difficult for farmers (and the scientist) to estimate the level of varietal mixture in millet.

The number and types of off-types to be found in rice varieties depends on the amount of farmer seed selection efforts (see also Chapter 4), the distinctiveness and duration of cultivated varieties and off-types, farmer variety portfolios and the range of varieties grown by other farmers in the village. Although some varieties seem to survive more easily as mix-ins than other varieties, the off-types found in farmers' fields can be considered a function of variety use and selection dynamics in both past and present.

Farmers' perceptions on off-types and strange off-types

Men and women said they see off-types in millet and rice. Women do not mind if other rice unsown varieties grow in their field. They consider this is a way to conserve varieties and to ensure subsequent access to such varieties (indirectly stimulating cross-pollination between varieties). Some old farmer varieties no longer cultivated persist in the fields as off-types.

However, gradually these farmer varieties will disappear and women claim that certain old longer-duration varieties are already lost. That farmers conserve varieties has been reported in other studies. Farmers in Chiapas in Mexico sometimes grow small areas of a particular maize variety 'not to lose the seed' because it was a 'good maize' that might be useful in the future, even though they do not know when or how (Bellon, 1996). The strategy of women rice farmers in The Gambia is less to consciously plant older varieties than to 'live and let live'. But even so, it is explicitly a genetic conservation strategy since it keeps older material 'in play'.

Most explanations on the origin of off-types given by both men and women are directly related to physical contingencies linked to the cultivation of the two crops (e.g. run-off water relocating seed in rice and ants in millet). But the unfamiliar off-types are mostly attributed to God or Nature. Both men and women agree that in both rice and millet such strange off-types do occur. This implies that men and women have a similar (tacit) understanding of changes in rice and millet. But among both men and women, there are big differences in awareness about the possibility to discover strange off-types in the field.

Whereas for rice, some of these strange off-types are tested and sometimes become new varieties, strange off-types of millet are not tested. Women seem to be more aware of the value of off-types than men. Even women who have never seen a strange off-type know what they would if they did encounter novel material. Other women, however, do not have the time for testing or are quick to discard strange off-types that do not meet their requirements. Men are not limited by lack of awareness. Some men mentioned that black millet could easily produce white millet and vice versa. A few mentioned they wanted to test off-types in the past. But men at times also report that they consider testing a typical female activity so this maybe a factor in their own lack of enthusiasm. It is also seems plausible to assume that in the early stages of millet cultivation, men also harvested off-types separately for testing, but over they years found out that millet works differently from rice. The millet that is sown is not always the same as what is harvested. The result may have been a general understanding that millet off-types are simply not suited to the kind of selection effort that women invest in rice. Possibly, millet off-types are regarded more in a negative way. Those men that did see millet off-types, often referred to brown- or red-seeded off-types. Red-seeded sorghum is said to have a more bitter taste than white-seeded sorghum. One woman also noted that red-seeded millet is probably more difficult to pound, because red-seeded African rice (*O. glaberrima*) is also difficult to pound. It is worth noting that stereotypes can be transferred (by analogy) across species by both men and women.

Discovery of new varieties by farmers

Chapter 5 showed that many more rice varieties exist than millet varieties. Because of the low cross-pollination rate in rice new varieties develop, whereas the high cross-pollination rate in millet inhibits new distinct varieties to develop. Following Slatkin's (1987) arguments, gene flow is a creative force in rice, whereas in millet, it is a constraining force. This partly explains why women more readily explained the possibility of strange off-types appearing in their fields. These plants will be easily recognised if they have distinct plant height, flowering period, husk colour or spikelet shape. Farmers with a sharp eye for detail even notice off-types that differ only slightly in spikelet appearance. Thus, recognising a difference in plant morphology, particularly in relation to the inflorescence, is the first phase of the selection process for new varieties. The second phase is testing of the distinct off-type on farm, to see whether it performs well and has the required height and flowering period. The third phase is testing in the cooking pot, once there is sufficient of the new rice to be eaten. The argument that off-types must be distinctive from existing varieties to be recognised and selected, before they can be further selected for more utilitarian characteristics has also been emphasised by Boster (1985) for cassava.

This selection process explains the large variation in inflorescence morphology typical not only of The Gambia (see Chapter 10), but of various crop farming systems world wide (see Lambert, 1985; Voss; 1992; Bellon and Brush, 1994). For millet, farmers predominantly rely on spike and seed characteristics to differentiate varieties, particularly seed colour and presence of bristles. In millet, however, differences in spike shape, bristle colour and bristle length are not as clear compared to rice, because of the genetic and morphological variation within varieties maintained by pollen flow. Morphological variation within varieties tends to be more continuous in millet, whereas in rice it can be defined in distinct classes. Additionally, it is harder to see differences in seed shape and size, which are not that clearly visible in the field or during selection when the seeds are still attached to the spike. Using inflorescence related traits to differentiate varieties seems to be a widespread among many food crops. Lambert (1985) mentions that Indonesian rice varieties show large phenotypic diversity and that farmers distinguish varieties by traits related to the inflorescence, such as husk colour and grain size, shape, texture and colour. Voss (1992) notes that farmers growing beans in Central Africa often use seed characteristics to differentiate varieties. For maize, farmers also predominantly use seed and cob traits to identify varieties and associate these traits with agronomic and use characteristics (Bellon and Brush, 1994).

It can be argued that, the lower the rate of pollen (gene) flow, the more it works as a creative force. However, it is obvious that as the rate of gene flow approaches zero, its creative force must also decrease. It seems likely that the rate of pollen flow of rice is near the optimum rate, but how close remains unclear. Possibly, the optimum rate is somewhat higher than that for rice (Figure 7.2). It would mean that more hybridisation takes place, but not too much for genotypes becoming unstable. In the case of beans in Central Africa, the cross-pollination rate is 2% (Voss, 1992), higher than for rice, and farmers grow mixtures of beans, on average containing 20 varieties, even higher than the number of mixed-in varieties in this study. It would be useful to know whether this might also be the case for sorghum, which has an average cross-pollination rate of 5% (Doggett, 1988). Ethiopian farmers often plant mixtures of up to 20 varieties in their field (Teshome *et al.*, 1999). This promotes gene flow and the creation of new genotypes, but does not lead to varieties losing their distinct characteristics. In addition to the factors discussed in Chapter 5, this might help explain the large numbers of sorghum varieties in use in Ethiopia.

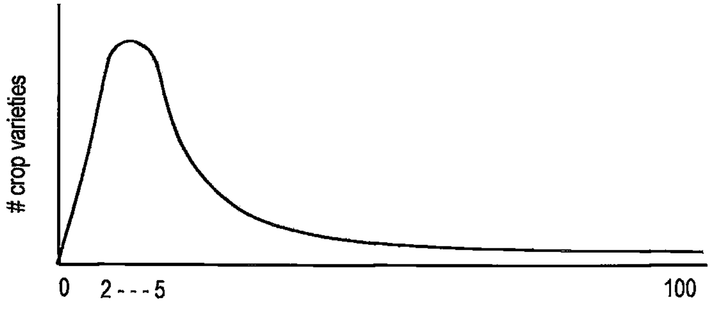


Figure 7.2: Relation between crop pollination rate and the number of varieties developing in farmers' fields for crops reproducing through seed.

This mechanism might also help to explain the large diversity in potato farming systems in the Andes. Cross-pollination followed by human selection is suggested to explain the large diversity in these systems (Quiros *et al.*, 1992). The cross-pollination rate in potato is higher than in sorghum, but new potato genotypes become fixed in one generation because potato is (in cultivation) a vegetatively propagated crop. The high cross-pollination rate in potato does therefore not lead to a blurring of distinct characteristics, as in millet or maize. In Irian Jaya farmers are aware that sweet potato volunteer seedlings are potential new varieties, which in combination with the vegetative reproduction explains the existence of over 1000 local varieties in an area that is not part of the centre of origin of sweet potato (Schneider, 1999). Another important factor, for both sorghum in Ethiopia and potato in the Andes, is the mixed cultivation of several subspecies and species, promoting the development of new genetic diversity.

Another factor that facilitates the development of many varieties is the seed multiplication rate. Bray (1986) mentions that rice has a higher multiplication factor than the comparable cereals wheat or barley. The level of the multiplication factor is also related to the growth conditions, rice often being grown in more favourable areas than wheat and barley. Because of the high multiplication factor, fewer multiplication cycles are needed to obtain from a few rice panicles an amount of seed sufficient for testing. Consequently, the testing cycle becomes shorter, and in only a few years farmers will know whether a rice variety has potential or not. Millet has an even higher multiplication rate than rice, but off-types lose their distinctiveness through cross-pollination. The multiplication rate of sorghum is also higher than of rice. This is presumably an important factor in facilitating the development of new sorghum varieties in Ethiopia.

A few women said they never saw rice off-types change, when selected for testing. This would imply that they never select F1 to F5-generation plants for testing. Allard (1988) indicated that the yields were low for first generation barley crosses, but increased tremendously from the F1 to the F5-generation through an increase in the number of seeds per inflorescence. Those women who claim off-types show no further change may be missing earlier generations because they are not 'impressive to their eye'. The implication, however, is that selection pressures during F1 - F5 generations are 'built-in' to on-going farming practices in ways not entirely clear. The matter requires further investigation.

7.5 Conclusions

It is possible to summarise the main findings of this chapter as follows:

- Because farmers locate their rice fields next to each other, pollen flow between varieties in different fields is possible.
- Because rice fields contain mixed-in varieties, pollen flow between varieties within plots and fields is possible. The calculations presented indicate that this 'current' is stronger and more influential than between plots and fields.
- Millet fields, usually, are rarely located next to each other and thus it is possible to infer that pollen flow between fields will be negligible.
- Since almost all farmers per village grow the same variety of millet, any pollen flow between fields is between populations of the same variety.
- Millet varieties also often contain some mixed-in other varieties (more in Kombo than in Foni), implying some pollen flow between varieties within fields.
- Rice varieties differ in the number and quantity of off-types they contain, which is related to morphological agronomic plant characteristics and the range of rice varieties grown by women in a village.
- Gambian women are effective in preserving a useful amount of rice genetic diversity through their seed selection methods, which should be acknowledged.
- Rice farmers do not mind limited levels of off-types in the field; they see it as a kind of insurance.
- Because rice is an inbreeder where there is limited amount of pollen flow, pollen flow is limited in rice, new genotypes can stabilise and maintain themselves easier than in millet.

- Women attribute the presence of off-types in rice mostly to running water; men's explanations for off-types in millet are more diverse: seed mixtures, ants, birds, God and water.
- Selection of seed for sowing next year and of off-types for testing are two completely different practices and should not be confused.
- In general, farmers think that strange off-types are caused by God or Nature. They do not have an explicit understanding of what exactly causes change in millet and rice.
- Women are more aware of the development of strange off-types in rice than men are for millet. It is clear that the difference in breeding system of rice and millet plays a significant part in women being more aware of the possibility of developing off-types in new rice varieties.
- Women separate, test and develop strange off-types into new rice varieties, whereas men do not do so for millet.
- For farmers to be able to separate strange off-types, the off-types need to be morphologically clearly distinct from existing varieties.
- Whether women separate strange off-types depends on the potential of these off-types, the availability of time, and the personal interest of the farmer.

8 The wild and the cultivated: Gambian rice and millet complexes

8.1 Introduction

It is often assumed that in traditional agriculture crops are enriched by gene exchange with wild and weedy relatives (Altieri and Merrick, 1987; de Wet and Harlan, 1975; Prain, 1993). Molecular and ecological analyses suggest a prominent role in evolution for interspecific hybridisation in numerous species complexes (Arnold, 1992). Another viewpoint is that it remains unclear whether frequent hybridisation events are purely accidental, or have a significant role in the origin and evolution of species (Rieseberg, 1995). There seems little hard evidence for the movement of valuable traits from wild relatives into crops (Wood and Lenné, 1997). This, however, does not mean that no new potentially valuable traits can arise from introgression (Jarvis and Hodgkin, 1999). Fertile progenies of hybridisation between two cultivated rice species resembled the parental phenotypes, which indicates it will be difficult to detect hybrid derivatives under natural conditions (Sano, 1989). This mechanism also applies to introgression between wild and cultivated species. Furthermore, plant breeders have used wild relatives as a source of valuable traits for various crops (Jarvis and Hodgkin, 1999; Ingram and Williams, 1984).

The number of studies describing farmers recognising and selecting new genetic variation that has occurred from natural introgression is limited (Jarvis and Hodgkin, 1999). The clearest examples are on maize in Mexico. In maize fields in Mexico teosinte, a wild relative that can hybridise with maize, is weeded out because it reduces maize yields, but some farmers also said that it can make maize stronger (Wilkes, 1977). Some farmers tolerate 'unproductive' teosinte in the field (Wikes, 1989). These farmers claimed that if maize × teosinte hybrids are cultivated for 3 years, it produces maize (Wilkes, 1977). A similar process is described for maize × *Zea diploperennis* hybrids, which farmers think improves the productivity and pest resistance of maize varieties (Benz *et al.*, 1990). In Ethiopia farmers tolerate the presence of wild relatives of sorghum in or around their fields to allow some introgression (Teshome *et al.*, 1999).

Wild rice is abundant in The Gambia, and can be found in many lowlands. Although wild millet does not occur in The Gambia (Brunken, 1977), weedy millet (intermediate type of wild and cultivated millet) can be found in every field. This chapter explores whether cross-pollination between species actually can happen in the field, and whether farmers' practices (consciously or tacitly) encourage or prevent cross-pollination and the selection of their products, in both rice and millet. Rice is discussed first and millet second. Each of these sections starts with a literature review on the possibilities of cross-pollination between the wild and cultivated rice and millet species.

8.2 Methods

Data for this chapter derive from observations of the flowering periods of both cultivated and wild plants for both rice and millet in the villages of Tujereng, Faraba, Kitti and Janack, together with field walks and informal interviews, field walks. Some data from the questionnaire conducted in 2002 are also used.

8.3 Rice

Domestication

Thirty years ago, different theories existed about the origin of the two cultivated species of the Oryza genus, but with the help of isozyme and molecular analyses all theories, but one, have been eliminated. The generally accepted theory is that *O. sativa* and *O. glaberrima* have different wild progenitors, which in turn have a common ancestor which spread over Gondwanaland before it broke up and became Asia, Africa, America and Australia (Khush, 1997; Second, 1982). Nowadays, it is also generally accepted that *O. barthii* (syn. = *O. breviligulata*) is the wild progenitor of *O. glaberrima* and *O. rufipogon* the wild progenitor of *O. sativa* (Oka, 1988). Whereas domestication of *O. sativa* possibly started about 9000 years ago (Chang, 1976), domestication of *O. glaberrima* may have been more recent, likely only about 3500 years ago (Portères, 1962). Portères (1962) thought *O. glaberrima* was domesticated in the inland delta of the Niger river in Mali because he considered it to be the centre of origin of *O. barthii*. The Gambia and Casamance are seen as a secondary centre of origin (Dania Ogbe and Williams, 1978). Isozyme and RFLP studies on the Oryza genus suggest that *O. sativa* was domesticated at various places in Southeast Asia and at different periods (Glaszmann, 1987; Second, 1982; Wang *et al.*, 1992). This explains why the indica varieties differ from the japonica varieties, which in turn can be differentiated into temperate and tropical japonicas. The larger genetic variation found in *O. sativa* compared to the limited genetic variation found in *O. glaberrima* is likely the result of genetic exchange between the japonica and indica subspecies (Second and Wang, 1992), and possibly also due to the difference in time of domestication.

There are several theories how *O. sativa* was brought to West Africa. The most common view is that Portuguese traders brought tropical japonicas from Indonesia to Guinea-Bissau, from where they spread to other West African countries. Consequently, most of the upland varieties grown in West Africa are tropical japonicas (Khush, 1997). Most of the lowland *O. sativa* varieties brought to West Africa belong to the indica subspecies (de Kochko, 1987a). This might be explained by the fact that wetland development of rice in West Africa was a particular emphasis of the colonial period. Most lowland rice varieties in Southeast Asia belong to the indica subspecies (Glaszmann, 1987; de Kochko, 1987b).

Gene exchange between species

Figure 8.1, adapted from Second (1991), shows the phylogenetic relationships between the various rice species in Asia and Africa. Chu and Oka (1969) report that hybrid swarms between *O. glaberrima* and *O. barthii* are frequently found, but hybrids between other species are rare. Isozyme (Second, 1982) and RFLP analyses (Wang *et al.*, 1992) show that *O. glaberrima* and *O. barthii* are more closely related to each other than most other species, which might explain the higher rate of introgression between these two species. Second (1991) suggests that introgression is possible between all rice species of the *O. sativa* complex[12] that grow sympatrically, except between the annual *O. barthii* and the perennial *O. longistaminata*. Other sources, however, report introgression is possible between these two species (Chu and Oka, 1969; Dania Ogbe and Williams, 1978).

It is often assumed that *O. sativa* is completely isolated from *O. glaberrima* and *O. barthii* by an F1 sterility barrier (Chu and Oka, 1969; Spillane and Gepts, 2001). Hence, the development of the Nericas (New Rice for Africa) based on the hybridisation of *O. sativa* and *O. glaberrima*

[12] Only those Oryza species closely related to *O. sativa* and sharing the same genome, see Vaughan (1989).

is considered a technological breakthrough (WARDA, 2001). However, Sano (1989) argues that pollen flow does happen, although unidirectional from *O. sativa* to O. glaberrima. Other studies suggest introgression in both directions occurs in the field (Second, 1982; Chang, 1976), and show that under experimental conditions introgression from *O. glaberrima* to *O. sativa* is possible, although at a low rate (Pham and Bougerol, 1993; 1996). Artificial backcrosses produced fertile progenies which resemble the parental phenotypes, indicating that under natural conditions it will be difficult to detect hybrid derivatives (Sano, 1989). This means that, for example, plants belonging to *O. glaberrima* can incorporate *O. sativa* genetic material but remain typically *O. glaberrima* to the eye.

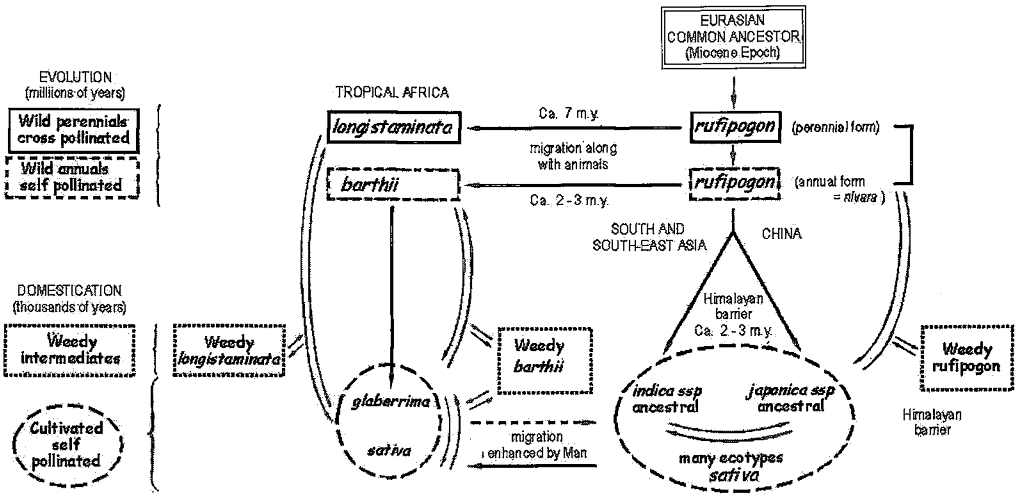


Figure 8.1: Phylogenetic relationships between the various wild and cultivated rice species in Africa and Asia (adapted from Second, 1991).

Although not within the scope of this study, it is interesting to note that in a field trial conducted in 2002 10 interspecific hybrids were found in *O. glaberrima* seed lots and one interspecific hybrid in an *O. sativa* seed lot producing two viable seeds, which confirms that there is some pollen flow between *O. glaberrima* and *O. sativa*. These two seeds were included in the molecular analysis described in Chapter 10.

In the past, interspecific hybrids or 'weedy' forms were called *O. stapfii*, but because they show a continuous variation between the various species this name does not indicate a particular discrete group of rice plants and is not in use anymore. Langevin *et al.* (1990) showed that in some cases 52% of the weedy forms were actually intermediate between the weedy and the cultivated type.

Morphology and habitat of wild rice in The Gambia

In The Gambia two species of wild rice can be found: *O. barthii* and *O. longistaminata*. The most apparent difference is that *O. barthii* can only multiply itself through seed, while *O. longistaminata* multiplies itself via rhizomes and seed. *O. barthii* has a purple/red (sometimes white) inflorescence, long awns, short, rounded ligule and a height comparable to that of *O. sativa*. *O. longistaminata* has a white husk, white, very long awns, long pointed ligule and is much taller than *O. sativa*. Both species have an erect panicle of which the branches spread similarly to *O. glaberrima*. Both species usually have a red seed colour, but occasionally also a white colour. The seeds have the shape of cultivated rice, but are much bigger. Gambian farmers call wild rice '*kamanimano*' in Mandinka because it resembles cultivated rice, yet is different. In the uplands farmers call an unrelated weed species also *kamanimano* because it resembles rice in the vegetative stage.

In general, both species start flowering before *O. sativa*, but there is also a considerable overlap. Further, *O. barthii* flowers slightly earlier than *O. longistaminata*. *O. barthii* is usually found in big groups in rice fields, while *O. longistaminata* is often found scattered in isolated stands.

Both species of wild rice are common in The Gambia. Literature sources are somewhat confusing. Some mention that wild rice grows in the uplands, while others indicate that wild rice only grows in the lowlands. If the transitional zones are regarded as lowlands (see Chapter 3), wild rice is only found in the lowlands. Wild rice is typically associated with fresh water ecologies but not with seasonally salt-water ecologies. In the associated mangrove ecology, where the swamps are flooded with salt water for 6 months each year, wild rice is very rare. In the rain-fed areas bordering the associated mangrove ecology, *O. longistaminata* grows in the rice nurseries without flowering. It maintains itself through its rhizomes. If it is transplanted into the rice fields it dies in most cases. Since *O. longistaminata* multiplies via rhizomes, it is possible that transplanted wild rice plants lack a well-developed root system and die when transplanted. In Janack, where only the cultivation of short duration varieties is possible, no wild rice can be found, although it may have grown there in the past. In the transitional zones, like in Faraba, *O. longistaminata* maintains itself through its rhizomes in the field for many years without flowering. Before the general decline in rainfall, 30 years ago, there was probably enough rainfall for the wild rice to flower.

Farmer management of wild rice

To the practised eye, wild rice is relatively easy to distinguish from *O. sativa* at the vegetative stage: the collar (near the ligule) of wild rice is more pronounced, it tillers more profusely and the angle of the tillers tends to be wider than that of *O. sativa*. An experienced woman will pull out wild rice as quickly as other grassy weeds. Women said that when wild rice is past tillering stage it is more difficult to recognise. Ligule shape was not mentioned by women. This is not surprising since it is of no real diagnostic value. *O. longistaminata* has a long pointed ligule (like *O. sativa*) and *O. barthii* a short rounded ligule (like *O. glaberrima*).

Since *O. longistaminata* multiplies through both rhizomes and seed, one would expect it to be a more serious weed than *O. barthii*, but observations in the field show that *O. longistaminata* is not as much a problem as *O. barthii*. When women plough their fields, they remove the rhizomes from the soil, which possibly explains why *O. longistaminata* is not as problematic as *O. barthii*. Another explanation might be that *O. barthii* is better adapted to ecological conditions in The Gambia than *O. longistaminata*.

As explained above, wild rice is rare in the associated mangrove ecology and most farmers also said they do not have it in their fields (Table 8.1). In fresh water swamps which are waterlogged, and where rice is transplanted every year, wild rice is not common. About 40% of the women who transplant rice said they do not have wild rice in their fields. Wild rice is commonest in the lowlands where rice is broadcast. Almost all farmers who direct-seed their rice in the lowlands said they have wild rice in their fields (Table 8.1).

It is apparent to the eye that there is less wild rice in the lowlands where rice is transplanted than in the lowlands where rice is direct seeded. One possible reason is that nurseries must be weeded in time to ensure good seedlings at the time of transplanting, whereas direct seeded rice does not have as strict a weeding deadline. Secondly, just before transplanting, the flooded field will be ploughed, eliminating the germinated wild rice, and submergence of the field will make it difficult for the remaining wild rice seed to germinate. So, transplanting is an important means to reduce the frequency of wild rice in the field. Furthermore, farmers cultivate every inch of the swamp suitable for rice cultivation, thereby diminishing the space for wild rice. So, even though swamps are the ideal ecology for wild rice, little is seen in a swamp where farmers actively transplant rice. However, wild rice growing just outside farmers' fields is left untouched.

Table 8.1: Percentages of farmers who recognise wild rice in their fields and the time of its removal in the different lowland ecologies, N = 132 (data from 2002-questionnaire).

	faro, sown	*faro*, sown and planted	*faro*, planted	*faro*, mangrove
not present	16	4	37	65
present, not removed	3	0	0	0
present, removed	82	96	63	35
during weeding	71	85	59	35
harvesting	11	8	4	0
both	0	4	0	0

The importance of timely removal of wild rice became clear at the flowering stage in Tujereng in 2002. Some farmers were discouraged because of the erratic rains and did not weed in time. When the rains became regular, rice was past the tillering stage and it was too difficult for the women to distinguish the wild and cultivated rice. In addition, some women who had recently changed from upland to lowland rice farming lacked a practised eye. This suggests that the more experience farmers have in rice farming, the smaller the opportunity for gene flow between cultivated and wild rice species. Fields not weeded in time were completely pink with the inflorescences of *O. barthii*. The lowlands of Tujereng showed a mosaic of pink fields with wild rice and green fields without wild rice. Because *Kamanimano* tillers a lot, elongates earlier and flowers earlier than rice, it shades the rice and reduces its yield.

A rare practice to reduce wild rice populations in the field is to harvest the *kamanimano* before it shatters its seeds. Nowadays, not many people do it, but some women said it was more common in the past. They said the grain of wild rice is very nice to eat in particular dishes: *satoo*, *munkoo* and *nyangkatang*. These are the same dishes for which *O. glaberrima* is said most suitable (see Chapter 5).

In 2002, wild rice was less abundant in Faraba and Kitti than in Tujereng. Faraba and Kitti had no mosaics of pink and green fields. In some uncultivated lowlands in Kitti wild rice was abundant but grazed by cattle and consequently it did not flower. In Faraba more wild rice grew in 2002 than in 2000, particularly in uncultivated fields in the transitional zones. In 2000, wild rice was removed during ploughing and weeding, while in 2002, wild rice grew freely because nobody bothered about it. The wild rice in this area in Faraba never flowered because of lack of water and is probably a relic population from the period when rainfall was higher. In summary, the pattern of wild rice distribution is a function of both climatic variation and farmer activity. Assessing whether or not there is gene flow between wild and cultivated species requires detailed knowledge of local farming strategies.

Rice volunteers and *O. glaberrima*

In this study volunteers are defined as plants that grow out of grain left in the field from the crop from the year before. In the past, *O. glaberrima* was more commonly grown in the uplands than in the lowlands (see Chapter 5). In those days the main advantage was its relative earliness. Nowadays, *O. glaberrima* can be found in the lowlands as an unwanted volunteer instead of as a crop. Farmers call it *Mani ba* (old rice) or *Lola* (standing straight). When talking about off-types, farmers in Kitti and Faraba usually make early mention of *Lola*. In those villages *Lola* seems to be more common than in Tujereng (see Appendix 8). Farmers do not want *Lola* in their crop because it is more difficult to thresh and to mill than most *O. sativa* varieties currently grown. In the uplands of Tujereng *O. glaberrima* is also found sporadically. In Janack, where there are no flooded lowlands anymore and where rice cultivation was stopped for about 10 years, no volunteer *O. glaberrima* was found.

Some farmers said *Mani ba* travels along with rice seed, while others said it is in the soil, or is carried there by ants, birds, water, etc. As explained in Chapter 5, some older women purposefully add a little bit of *Mani Ba* to their seed. Most farmers, however, try to keep it out of the seed for sowing and during harvesting often use a calabash, or similar, in which they can keep any panicles separate.

In most fields volunteer *O. glaberrima* ripens earlier than cultivated rice. Early flowering enables *O. glaberrima* to survive years of severe drought. However, there may be limitations to its survival capacity. In Janack, where rice cultivation stopped for about 10 years, but then resumed, no *O. glaberrima* was found.

In uncultivated fields in the transitional zones in Faraba and Kitti, volunteers of both *O. sativa* and *O. glaberrima* can be found. In most cases *O. glaberrima* was the first rice to flower and in a few cases even to ripen, while *O. sativa* was still elongating. *O. glaberrima* seems to be more common as a volunteer than *O. sativa*. Since *O. glaberrima* only makes up a very small part of the seed, it must be judged a more successful volunteer than *O. sativa* in Gambian conditions. Some women also said that if both species would make up an equal percentage of the sowing seed, *O. glaberrima* would outcompete *O. sativa*, because it tillers much more than *O. sativa*.

Chances of cross-pollination between species

Farmers occasionally see rice plants in their field without seeds, which they call *mani fufe* (literally 'useless rice'). The difference between *kamanimano* (wild rice) and *mani fufe* is that, although they often have many morphological similarities, *kamanimano* produces seed, while *mani fufe* does not. Another difference is that *kamanimano* is limited to the lowlands, while *mani fufe* can grow in both uplands and lowlands. Women said it sometimes just happens *mani fufe* appears in your field. *Mani fufe* is the result of cross-pollination between cultivated and wild rice or between *O. sativa* and *O. glaberrima*.

As was mentioned above, in a field trial conducted in 2002 11 *mani fufe* plants were observed which are the result of cross-pollination between *O. sativa* and *O. glaberrima*. In 2001, one such plant was observed in a field trial. During observations of farmers' fields in 2000 and 2001, respectively two and one *mani fufe* plants were noticed with morphological resemblance to wild rice. It was not clear whether they were the result of cross-pollination of wild rice with *O. glaberrima* or with *O. sativa*.

Although *O. glaberrima* (both as volunteer and as mix-in added to seed) often flowers earlier than cultivated rice, there is still considerable overlap in flowering. Some *O. glaberrima* plants also flower later than *O. sativa*. This means that cross-pollination between *O. glaberrima* and *O. sativa* is possible. Possibly, chances of cross-pollination decrease in the future, as only older women (and a minority of Manjago who recently migrated from Guinea-Bissau) mix-in *O. glaberrima* in their seed.

Cross-pollination between wild and cultivated rice is not possible in the upper stretches of the transitional zone. In years with good rainfall wild rice is weeded. In years with poor rainfall it is too dry for wild rice to flower. In the other parts of the fresh water lowlands wild rice usually flowers earlier than cultivated rice, but there is still considerable overlap in flowering. The most significant overlap tends to occur with early rice varieties. Late varieties have little or no overlap in flowering. The degree of overlap also depends on the time of planting or sowing of cultivated rice. This means that any cross-pollination between wild and cultivated rice must be restricted to the flooded fresh water lowlands or the wetter parts of the transitional zone. Because the number of wild rice plants is highest in the wetter parts of the transitional zone, the chances of introgression are highest in these areas.

Because O. glaberrima and wild rice both tend to flower earlier than cultivated rice, there is also considerable overlap in flowering between wild rice and *O. glaberrima*. The above is summarised in Table 8.2.

Table 8.2: Overview of possibilities for cross-pollination between the various *Oryza* species in various ecologies of The Gambia.

	O. sativa × *O. glaberrima*	*O. sativa* × wild rice	*O. glaberrima* × wild rice
uplands	yes	no	no
upper stretches of trans. zone	yes	no	no
fresh water lowlands	yes	yes	yes
mangrove ecology	no	no	no

8.4 Millet

Wild relatives of millet

There is still a lot of confusion about the nomenclature of wild millet, cultivated millet and the intermediate forms. Renno *et al.* (1997) possibly hoped there would finally be general agreement about the nomenclature as suggested by Van der Zon (1992). Van der Zon (1992, in Renno *et al.*, 1997) recognised three subspecies in pearl millet: *Pennisetum glaucum subsp. glaucum* for the cultivated phenotype, *P. glaucum subsp. violaceum* (Lam.) A. Rich. for the wild phenotype, and *P. glaucum subsp. sieberianum* (Schlecht.) Stapf & Hubb. for the intermediate ('*shibra*') form. This nomenclature is based on the regrouping of Brunken *et al.* (1977), who suggested that the wild, intermediate and cultivated types belong to the same species. Artificial crosses between wild and cultivated plants produced fertile progeny and a complete array of intermediate phenotypes, confirming that the wild, intermediate and cultivated forms belong to the same species (Marchais and Tostain, 1985).

However, more recent literature (Poncet *et al.*, 1998; Kaushal and Sidhu, 2000) continues to show a wide variation in the naming of cultivated and wild millet forms. If the degree of successful fertilisation is used to indicate the relatedness of the various forms - also studied by Kaushal and Sidhu (2000) - the nomenclature suggested by Van der Zon (1992) is still the best and, consequently, is used in this study.

Domestication

Different regions in Africa have been proposed as the area of domestication of pearl millet, but now it is generally agreed that domestication took place in the Sahel zone of West Africa, most likely in Niger and Mali, where the greatest morphological (Brunken *et al.*, 1977) and enzymatic diversity (Tostain, 1992) was found. The wild progenitor also occurs in the drier northern part of this zone. It remains unclear whether climatic conditions and plant distributions of the wild and cultivated millet have remained unchanged since domestication took place. The high enzymatic diversity of early millet and its divergence from West African wild millets suggest several domestications at different places (Tostain and Marchais, 1989). The data do not show that a single place of domestication is impossible, but less likely. The extensive diversity found in the crop today might also be further explained by introgression with the wild millet subspecies, followed by a quick dispersal (Brunken, 1977; Tostain, 1992).

Hybridisation of wild and cultivated millet

In the areas where wild and cultivated forms of millet are in contact the frequency of the intermediate form ranges from 5 to 30% (Rey-Herme, 1982, in Renno and Winkel, 1996). In Niger *shibra* plants (an Indian word for the weedy, intermediate form) make up on average 15% of the plants in cultivated fields (Ndjeunga, 2002). Case studies in Senegal and Niger provide estimates of fertilisation rates of wild millet by cultivated millet of 31% and 19% respectively (Marchais and Tostain, 1992). This information indicates that there is considerable pollen flow between the wild and cultivated forms, and raises the question how these two forms remain distinct. Two factors are considered to maintain this differentiation: reproductive isolation and reproductive barriers (Renno and Winkel, 1996; Renno *et al.*, 1997). Wild millet produces more tillers, and over a longer period, thereby extending the flowering period more than the cultivated millet. Consequently, wild millet is in temporal isolation during more than half of its reproduction period, but cultivated millet is not. Robert *et al.* (1991) show that there is a soft reproductive barrier through which homogamy is promoted when wild and cultivated forms grow sympatrically. Amoukou and Marchais (1993) noted that hybrid seed derived from crosses between cultivated and wild plants are less viable than seed from cultivated plants. This could be important in the sense that farmers, when thinning, will eliminate the less vigorous plants which will tend to be intermediate forms (Renno *et al.*, 1997). Elimination by farmers of wild and intermediate forms seems to differ. Wild millet has a hairy limb whereas cultivated millet has a glabrous limb, which makes identification and removal of wild millet in an early stage easy (Bono, 1973, in Marchais and Tostain, 1992). The wild form does not grow in The Gambia, and farmers find identification of intermediate forms at an early stage less easy, because the plants do not have a hairy limb are at this stage not clearly different from cultivated millet. Similarly, farmers in Niger said they can only recognise *shibra* millet when it is mature (Ndjeunga, 2002).

Although wild millet can be found in Senegal, so far, it has not been identified in The Gambia. But the intermediate form (*shibra*) can be found in all millet fields in The Gambia (Brunken, 1977). *Shibra* plants often have one or more of the following characteristics:

- easily shattering seeds,
- seeds remaining covered by the petal leaves,
- prolific tillering,
- much secondary and sometimes tertiary branching,
- slender stems and leaves,
- thin spikes with low flower density.

It is somewhat difficult to define *shibra* millet, because of a morphological continuum between *shibra* and cultivated forms. The clearest form of *shibra* millet has thin, short spikes of which the seeds are completely covered by the petals, and it looks as if the plant does not carry any seed: That is why farmers call it *nyo fufule* (i.e. useless millet in Mandinka). There are also plants with longer spikes and visible, though small, seeds, which shatter even if the spike is touched lightly. Then there are *shibra* forms more closely resembling the cultivated forms, of which seed shatters only if some force is applied. Of yet other forms, seed only partly shatters during harvesting and transport to the compound. This last type is neither typical cultivated millet, nor typical *shibra* millet. Marchais (1994) suggests that this continuum is common in many parts of Sahelian Africa.

Shibra plants are found anywhere in the field in a seeming random distribution and are rare outside millet fields. Exact figures are unavailable, but my own estimation is that less than 5% of the millet plants in the fields examined were *shibra* millet. This is lower than the estimates given by Rey-Herme (1982) and Ndjeunga (2002) for areas where cultivated and wild millet grow sympatrically, but is also logical given no wild millet is found in The Gambia.

Millet volunteers

In this study, volunteers are defined as plants growing from grain left in the field from the crop from the year before. In general, it is more common to find millet volunteers in abandoned fields than rice volunteers. Millet volunteers are usually shorter in height and are smaller than cultivated millet, probably because of less ideal growth conditions, but do not show any characteristics of *shibra* millet. It is rare to find *shibra* millet growing as volunteers. Most likely, the ratio between *shibra* and cultivated millet is the same in cultivated and abandoned fields. Volunteers are not weeded, and eventually end up as bird food. In some cases, when many volunteers are growing in an abandoned field next to fields of cultivated millet, a considerable rate of cross-pollination can be expected. Volunteers and the cultivated millet usually belong to the same variety. If different varieties are grown in a village, these varieties share the same genetic background to a large extent (see Chapter 10). Hence, it is unlikely volunteer plants have much effect on the genetic make-up of the cultivated millet.

Farmer management of *shibra* millet

Farmers were interviewed about *shibra* millet for this study. Some farmers said they can recognise *shibra* millet during weeding, while others said it is only recognisable during or after flowering. Some farmers said *shibra* millet is fairly easy to recognise for experienced farmers, but that it is difficult for children. Others said they do not have it in their field. Recognition is most difficult at the vegetative stage - in some cases the stems and leaves are much thinner than that of the cultivated millet, allowing identification. Only when the millet starts elongating, do the differences become clearer. At this stage, little weeding is done because the leaves can easily cut your skin. At flowering stage, the *nyo fufule* can be distinguished easily, but the plants are now too big to remove. So, farmers who remove *shibra*, mostly deal with it at harvesting time, by not harvesting it.

Based on the answers of the questionnaire there is no difference in frequency of occurrence of *shibra* millet in *sanyo*, *suno*, and *majo*. About 33% of the farmers said they do not have *shibra* millet in their field. Of the 67% who said they did, about two third removes the *shibra* millet, mostly during harvesting. In Kombo and Foni, where *sanyo* is grown, some farmers said they remove the *shibra* after harvesting, at the stage of the removal of the bristles: When removing the bristles it is easy to recognise *shibra* millet, since the seeds drop easily in the rough process of bristle removal. In Kiang and Fuladu farmers grow *suno* and *majo*, respectively, which does not have bristles and after harvesting the spikes are collected and taken home directly. Through the removal of the bristles, it is be easier for farmers to distinguish *shibra* millet from *sanyo* than from *majo* or *suno*.

Farmers also harvest spikes that do not shatter, but whose seeds are relatively easy to remove and whose flower density on the spike is less than that of the ordinary millet. Such spikes are neither typical *shibra* nor typical cultivated types, but rather can be described as cultivated types with some clear *shibra* characteristics. If farmers do not apply any selection such spikes also end up in the sowing seed. Farmers who do spike selection will not select such spikes as sowing seed. However, because of cross-pollination, genotypes of the *shibra* will remain in the sowing seed. Farmers do not realise that the *shibra* millet can affect the cultivated millet through cross-pollination. Some farmers think that when millet plants begin to display *shibra* characteristics this is due to wrong cultivation (too little fertiliser) or poor storage (too much sun).

8.5 Discussion

For both rice and millet, a fertilisation barrier limits cross-fertilisation with wild and weedy relatives, more for rice than for millet (Second, 1982; Chang, 1975; Pham and Bougerol, 1996; Renno *et al.*, 1997; Robert *et al.*, 1991). Thus despite wild and domestic species of rice showing a considerable overlap in flowering, actual successful fertilisation rates are likely to be very low.

The frequency of wild rice differs between ecologies. In the upland ecology wild rice simply cannot survive. In the upper fringes of the transitional zones wild rice is uncommon; if it grows there, it will not often flower. In the associated mangrove swamps wild rice is also rare. It is only in the fresh water lowlands where wild rice is common. It is in those parts too dry for transplanting, where rice is broadcast, that wild rice is most common. There seems to be little difference in the occurrence or frequency of *shibra* millet in the various millet ecologies.

There is an interesting difference between weeding practices for millet and rice. While women remove the wild rice during weeding, many men do not weed *shibra* millet, and those who do, mostly remove it during harvesting. One explanation is the method of weeding. Rice is weeded slowly but carefully by hand, while millet is weeded in a fast and rough way, sometimes overlooking weeds and cutting millet plants. For transplanted rice, the ploughing of the field can also be seen as a (de facto) weeding of wild rice. In general, tillage reduces the occurrence of wild relatives (Nabhan, 1985). Secondly, it is easier to distinguish wild rice from cultivated rice, than *shibra* millet from cultivated millet. By the time that *shibra* millet is more distinguishable, it has grown too big to remove from the field. The third, and probably main, reason is that *shibra* millet does not compete with cultivated millet the way that wild rice competes with cultivated rice. In The Gambia *shibra* millet is only present in small numbers in millet fields and seemingly cannot outcompete the cultivated millet, while in rice fields, if wild rice is not properly taken care of, wild rice out-competes the cultivated rice resulting in a major decrease in yield. So, there is a very clear benefit in weeding wild rice. In Senegal and Niger, where wild and *shibra* millet occur much more frequently, hairy millet plants are weeded at an early stage because hairiness is a typical characteristic of wild millet and hence it is easy to distinguish (Marchais and Tostain, 1992). In Mali, where wild millet is also common in farmers' fields, plants with narrow leaves are thought to be wild and weedy millet and are removed during thinning (Sandmeier *et al.*, 1986). Compared to weedy millet in The Gambia, wild millet is more common in those countries and untreated has a bigger impact on yield.

While women promote chances for cross-pollination between cultivated varieties through their farming practices (see Chapter 7), they reduce chances for cross-pollination between cultivated and wild rice by weeding, transplanting and ploughing. The removal of wild rice happens long before flowering. For millet, removal happens only after flowering, which increases the chances for cross-pollination between *shibra* and cultivated millet. For millet, the many intermediate forms that grow in The Gambia are neither typical cultivated, nor typical *shibra* and are likely the product of recurrent crosses between cultivated and *shibra* millet. Such stable coexistence of cultivated and weedy millet is known in other parts of Sahelian Africa (Marchais, 1994).

The question remains whether farmers also conserve wild relatives in their fields as a possible food source, just like some farmers conserve *O. glaberrima* as insurance. Some women said that it was more common in the past for people to harvest wild rice for food. Indirectly, it indicates that food security in the 'hungry season' has improved in recent years. Harvesting seed from weedy millet growing in late millet fields in The Gambia is not possible, since it flowers earlier than the cultivated millet and its seeds are sucked empty by blister beetles. Exactly because the earlier flowering weedy millet only produces spikes without seed it is named *nyo fufule* (useless millet). In Mali, where wild and weedy millet also flowers before the cultivated millet, it is sometimes harvested for food during the hungry season before the cultivated millet is ripe (Sandmeier *et al.*, 1986). So, although farmers in Mali try to eliminate it during thinning, they also harvest it for food.

8.6 Conclusions

It is possible to summarise the main findings of this chapter as follows:

- Wild relatives of rice are most abundant in particular rice fields, mostly in the wetter part of the transitional zone.
- Weedy millet can be found in all millet fields, although in low numbers.
- Pollen flow between cultivated and related wild and weedy species occurs in rice and millet in The Gambia.
- Compared to intra-specific gene flow, gene flow between wild and cultivated rice is less due to lower frequency of wild species in farmers' fields and due to fertilisation barriers. For millet, gene flow between weedy and cultivated types might be higher than between cultivated varieties because farmers usually only grow one variety in their field and most farmers per village grow the same variety. The importance of interspecific gene flow was not studied, however.
- To be able to recognise wild rice at a young stage requires a 'practised eye' (specialised knowledge). The same is true for weedy millet. The morphological distinguishability of the wild and weedy relatives is easier after flowering.
- In fields where wild rice is abundant women weed it to prevent competition at later stages.
- Because weedy millet does not compete much with cultivated millet in The Gambia, there is no need for farmers to remove it in an early stage.
- Gambian farmers manage introgression between cultivated and wild and weedy relatives via their farming practices: if the wild or weedy relative competes severely with the cultivated species, it is weeded. But if it can serve as a food (wild rice), farmers are more willing to leave it in the field.
- Gambian farmers do not consciously promote hybridisation between wild and cultivated species.

9 Gender, gene flow and crop diversity[13]

9.1 Introduction

The first research question of this thesis was how farmers manage gene flow, and which factors play a crucial role. This chapter will focus on the role of gender in farmer management of gene flow and crop diversity. Very early during the fieldwork it became clear that male and female farmers responded in different ways about variety management. Men often argued that it is typical for women to differentiate so many rice varieties, and that men are not able to differentiate all those varieties. Men would often say that millet is millet and that there are actually no real differences between plants. However, if you look at field level, a huge variation in plant height, spike size, bristle length, bristle colour, etc is visible. Women would sometimes say that men lack interest in variety management and do not bother about millet varieties. If you go to women's fields, women will explain the characteristics of the different rice varieties, and show you why a particular plant belongs to this variety and not to another. So, it seems that women care more about crop diversity and variety characterisation than men do. In Chapters 2 to 8 various aspects were related to gender, gene flow and crop diversity. In this chapter those different aspects are linked together and explained in a cohesive way.

9.2 Change in farming systems over time in The Gambia

Rice and millet are the two most important staple foods in The Gambia. The most likely explanation for the importance of both crops is that the very different ecologies needed for both crops are both common in the country. The Gambia constitutes one of western Africa's ecological, social, and cultural frontiers (Brooks, 1993). As such it is also part of a transition zone between savanna and forest agriculture. South of The Gambia, in Casamance, Guinea Bissau, Sierra Leone and Liberia, rice is the main staple food, whereas to the north and north-east of The Gambia, pearl millet and sorghum are the main staple foods, except in areas near rivers (Figure 9.1). According to Tosh (1980) agriculture in the savanna zone requires more and better organised labour, because of the shorter cultivation season and steeper labour peaks. Consequently, sharing farming tasks between men and women is more common in the savanna compared to the forest zone: for example, men clear and prepare the land, women do most of the planting and weeding, and all take part in the harvest.

In The Gambia a different division of labour is practised than in other parts of West Africa: women are responsible for the cultivation of rice and men for the cultivation of millet. According to Webb (1992), gendered agriculture in The Gambia is sometimes called the Mandinka farming system, although it is as typical of the ecology as it is of the ethnic group. Because swamp rice cultivation is less common in the former Mandinka Wuli kingdom in Eastern Gambia and yet the organisation of labour in farming was gendered is taken to indicate that this labour organisation has an ethnic origin. In Wuli men used to grow millet, sorghum, groundnuts and beans, and women findo (hungry rice), chickpeas, groundnuts and vegetables in the same fields (Weil, 1984). In the few available depressions, women grew rice. According to Weil (1984), this gender divide reflects labour requirements of the various crops: vegetables and rice require daily, or at least regular, care and are thus women's responsibility. However, groundnut, a male crop, also requires regular care. So, there must be more to a gender-based division of labour than labour requirements. A second factor is whether a crop is meant for subsistence or for sale (like groundnut).

[13] This chapter is presented at the AEGIS Conference, School of Oriental & African Studies, London, 29 June - 2 July 2005.

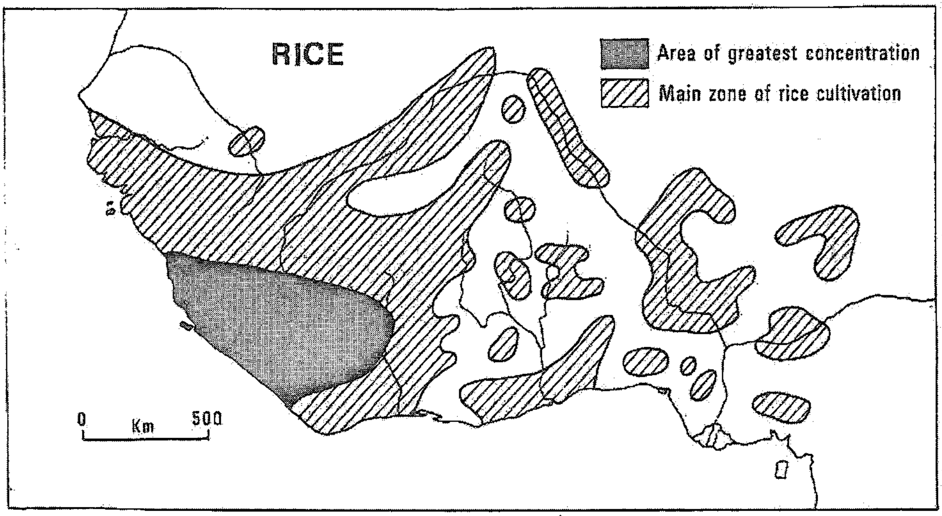


Figure 9.1: rice growing areas in West Africa (from Peel and Richards, 1981).

Before 1860, rice production was primarily the domain of women, but men had the responsibility for certain tasks, of which the most notable one was the preparation of the land prior to transplanting (Watts, 1993). It was only around 1860 that a transformation occurred in Mandinka agriculture from task-specific to crop-specific gender roles (Watts, 1993; Swindell, 1992; Carney, 1993). With the booming groundnut industry, Mandinka men began to monopolise groundnut production and consequently rice farming became entirely women's work. Furthermore, compared to swamp rice cultivation, groundnut has the advantages that it is less subject to locust ravages and less labour intensive (Swindell, 1980). Although before 1850, rice was an export crop, it later changed into an import crop, and grown locally for subsistence (Watts, 1993). Nowadays, rice is grown by women, whereas millet is grown by men. It is only the clearing of rice fields that is still done by men (see also Chapter 2 on land ownership) in most cases.

For almost all ethnicities in The Gambia, agriculture today is gendered. In the northern part of Casamance, south of the Gambian border, Olga Linares (1992) speaks of a process of 'Mandingisation' of the Jola: The Jola adopting the culture and religion of the Mandinka. In The Gambia it seems likely that this not only happened with the Jola, but also with other tribes (see Box 2.1).

There are, however, also some divergent patterns visible in The Gambia. In those areas where rice cultivation is not possible, or not possible anymore because of reduced rainfall, women cultivate their own millet and groundnut fields, separate from the men's. In the irrigated rice areas, men also work in the rice fields (Carney, 1993). They have control over women's labour and over the income generated from the sale of rice paddy (Carney, 1993). The irrigated rice fields are the only areas where farmers can produce a surplus of rice, which can be sold. A third divergent pattern is visible in farming by the Manjago who settled recently (over the past 50 years) in The Gambia and who come from Guinea-Bissau. In Manjago culture, there is no gendered divide in crop cultivation and men and women cooperate in rice farming.

9.3 The role of gender in farming systems in Western Africa

In many areas of western Africa agriculture is gendered by tasks: men usually do the clearing and ploughing of the fields, women mostly do the weeding, while the task division is less straightforward for sowing and harvesting. This type of labour division is, for example, common in Southwest Casamance, south of The Gambia. According to the traditional labour division in Southwest Casamance, south of the Casamance river, men prepare and plough the rice fields, while women transplant and weed the rice (Linares, 1981). However, in the northern part of Casamance, close to The Gambia, the labour division is similar to that in The Gambia (Linares, 1981; 1992). The labour division in the coastal areas of Guinea-Bissau and Guinea (Conakry) is very similar to that in Southwest Casamance (Linares, 1981). In the villages Kogbotuma and Mayogba in Sierra Leone men prepare the uplands for rice cultivation, while weeding is a typical female task (Johnny *et al.*, 1981). In the cases in Southwest Casamance and Sierra Leone, both women and men are involved in harvesting (Linares, 1981; Johnny *et al.*, 1981). Yet, in other areas in Sierra Leone upland rice farming generally is under the control of men, with women tending the swamp farms and growing many of the secondary crops (Linares, 1981). In the northern part of Sierra Leone, where no typical swamp lands exist, both men and women are involved in rice cultivation (interestingly, men doing the sowing), while groundnut and maize cultivation and gardening are the sole responsibilities of women (Donald, 1970). In Northwest Sierra Leone tasks in rice farming are distributed among men and women in different ways in different areas and between different ethnicities (Jusu, 1999).

It also happens that there is no clear division in tasks at all between men and women for the main staple crops, while gardening is women's responsibility. In the village of Kala, north of Ségou in central Mali, where pearl millet is the main staple crop, there is no division in tasks between men and women, except for the ploughing, because women rarely handle the oxen (Toulmin, 1992). In the village of Dukomba, lying southeast of Ségou in Mali, where farmers do not use ox plough, and sorghum and millet are the main crops that are grown, there is no gender division in tasks (Lewis, 1981). Both villages are of Bambara speaking people (distantly related to the Mandinka in The Gambia). The Maninke of Djoliba, southwest of Bamako in Mali, more directly related to the Mandinka of The Gambia and whose main crop is sorghum, also do not have a sexual division in farming tasks (Jones, 1970). Among the Manjago in The Gambia, who migrated recently (less than 50 years ago) from Guinea-Bissau, there is also no clear gender division in rice farming tasks, except the felling of trees. These cases indicate that the gender division in farming in The Gambia is quite particular.

They also indicate that labour organisation is not only regulated by practical agronomic factors, but also by economic and socio-cultural factors (Guyer, 1980; Whitehead, 1985). Likewise, in the case of rice farming in Southwest Casamance, the equivalence between men and women is not only reflected in the equal number of days they work in the rice fields, but also in tradition and religious rites (Linares, 1985). In Africa gender and household-level social relations play key roles in organising access to, and control over, productive resources (Berry, 1989). The household unit is identified as 'the site of separable, often competing, interests, rights and responsibilities' (Guyer and Peters, 1987; Schroeder, 1993). Guyer (1984) argues that men's and women's different working rhythms are also related to their institutionalised means to mobilise labour and that the resulting differences in cropping systems are a reflection of social power, rather than the result of gender as a natural characteristic. In Sierra Leone it is easier for men to organise a large labour force than it is for women (Johnny *et al.*, 1981). Hence, men concentrate on upland farming which is characterised by labour peaks which can only be mitigated by large labour groups, while lowland rice farming and vegetable gardening have more of a constant labour requirement. This also helps explain the organisation of labour and crops in The Gambia.

Guyer (1984) argues that these differences in labour organisation are also related to the time of introduction of the crops: indigenous staples are characterised by complex and ritualised labour organisation, whereas recently introduced staples tend to be individuated, gender-specific and secular. The farming system in The Gambia is perhaps something of an exception, since rice, a traditional staple, is often grown by individual women. But Guyer's argument is valid in the sense that the introduction of a new crop in a farming system is a medium for, and expression of, the re-negotiation for the organisation of labour (1984). This explains why cash crops, usually foreign in origin, tend to increase the overall gender-based division of labour (Boserup, 1970). This happened with the introduction of groundnuts in The Gambia, which resulted in rice being pushed into the women's domain. It is also interesting to note that in southern Africa the introduced crop maize, predominantly used for subsistence, is grown by women (Guyer, 1984), while in Senegambia the introduced crop groundnuts, predominantly used for sale, is grown mostly by men. Technical innovations, such as changes in crop repertoire, are seen as a vehicle for, and a consequence of, attempts by different groups within a community to exert control over the production process (Guyer, 1984).

Apart from the time of introduction of a crop, the use of a crop as income source is another key factor influencing labour organisation. Around and Southwest of Mopti in Mali, where vast plains are flooded during the rainy season, rice is the main staple and only cash crop and is only cultivated by men (Nyanteng *et al.*, 1986). Common cash crops in Mali, as groundnut and cotton, are not suitable for cultivation in this area. This indicates that the gender divide in rice cultivation is related, to some extent, to its use as a cash crop. Also in Sierra Leone, where local trade in rice is very common, men are involved in rice cultivation (Johnny *et al.*, 1981; Richards, 1986). In other cropping systems it is common that men take the responsibility for the cash crops, while women have the responsibility for the subsistence crops (Howard, 2003). A gender division of crops based on value also occurs in the highlands of Papua New Guinea. Men tend to grow crops which are used for transactions and expression of status, while women grow crops for consumption (Sillitoe, 2003).

9.4 Gender as nature and nurture

It is argued that conflicts of interest between men and women are not generic conflicts of interest, or natural antagonisms, but, like other conflicts of interest, rooted in the nature of social relationships (Whitehead, 1984). Likewise, Guyer (1984) argues that differences in men's and women's labour organisation and the resulting differences in cropping systems are a reflection of social power, rather than the result of gender as a natural characteristic.

In the past, and even now, some scholars have tried to assign aptitudes to men or women, as typical male or female characteristics or talents. Shiva (1988) argues that it is possible to classify characteristics as either masculine or feminine and as, respectively, destructive and creative characteristics, but more important, that all men and women have a combination of both categories in varying ratios. Durkheim, one of the founding fathers of social science, argued that masculine aspects of culture are related to power and that feminine aspects are related to compassion (Mestrovic, 1992). An important question therefore is to try and resolve which characteristics might be typically masculine and typically feminine, and whether it is possible to locate these differences in nurture or nature. To what extent do nature and nurture influence the various male and female characteristics and in which ways? To what extent do we acquire our talents via genes from our parents, and to what extent do we acquire our talents by learning from other people? To separate out endowments from acquired characteristics is, however, impossible for a wide range of features (Block and Dworkin, 1977; in Elson, 1991). One of the main problems is how to explain both the enormous observable variation in cultural understandings of what the categories ‘man’ and ‘woman’ mean, and the fact that certain notions about gender appear in a wide range of different societies (Moore, 1988).

It seems plausible to draw a parallel between the regulation, or basis, of male and female characteristics and that of emotions (without discussing which emotions are male or female). It is argued that emotions and diversity in emotions are the result of the interaction between nature and nurture, or between genes and the social environment (Griffiths, 1997). Whereas the genetic basis of emotions is likely distributed over all 13 chromosomes of man (since man is a diploid making 26 in total), the genetic differences between men and women are likely only linked to the crippled X-chromosome (the Y-chromosome only carried by men). This means that the differences in male and female characteristics, both physical and emotional, are linked to the X and Y chromosome. Since there are very clear physical differences between men and women, there might also be emotional differences between men and women. In future, it might be possible to disentangle endowment from acquired characteristics, nature from nurture, by looking at the impact of the various hormones regulating physical differences between men and women on emotional differences. But as for now, it is difficult to identify characteristics as either male or female. None of this would alter a true social (or political) fact that in many, different cultures that women have a secondary status in society (Boserup, 1970).

9.5 Gender in relation to genetic diversity

For the time being, further speculation on biological and social constructed components of gender seems hazardous for lack of real data. The question then is how to proceed with the argument that women play a crucial role in conserving and creating diversity (Howard, 2003, Shiva and Dankelman, 1992). The importance of the availability of diversity (biodiversity, crop diversity and genetic diversity) is that it provides the opportunity to farmers to keep options open. Diversity does not necessarily lead to yield increases, but is more linked with yield stability. Shiva (1988) argues that women use more sustainable farming systems whereas men are more interested in short term gains. It is also stated that ‘domestication has often depended on the observational powers of women who historically have been most associated with seed selection and thus with noticing new varieties which spontaneously appear in the field’ (Prain, 1993). This would suggest that women ‘naturally’ are more interested in biodiversity than men are. An obvious first question about gender and crop diversity is whether men and women deal with diversity in different ways. Above it was already argued, however, that many economic, socio-cultural and ecological factors shape farming practices and thus also the diversity management practices. It also means that to be able to answer the question conclusively whether men and women deal with biodiversity in different ways, the debate on the share of, and interaction between, nature and nurture needs to provide some tangible outcomes. Here, therefore, we proceed cautiously and within the limits of actual evidence. Several cases will be reviewed below concerning how men and women deal with biodiversity, after which the information collected in this case study concerning The Gambia will be presented and analysed.

One way to link up the discussion on gender and diversity is to link it up to research paying much attention to particular crops, while paying less attention to other crops. For example, in Southwest Zimbabwe both men and women are involved in agriculture, but research attention to ‘women’s’ crops like sorghum, millets, groundnuts and other legumes has lagged behind by ‘men’ crops such as maize, cotton and sunflowers (Van Oosterhout, 1996). In the case of The Gambia, more research world-wide has been conducted on rice, the most important Gambian women’s crop than on millet, the most important men’s staple crop in The Gambia. But it is true that research focuses on a rather narrow range of crops grown world-wide and excludes indigenous crops grown in particular regions or in relatively small areas. Many of these indigenous crops are vegetables. In many cultures women are responsible for vegetable cultivation (Van Oosterhout, 1996; Dhamotharan *et al.*, 1997; Linares, 1981; Johnny *et al.*, 1981; Donald, 1970; Jones, 1970; Magistro, 1997; Schroeder, 1997b; Howard, 2003). So, to some extent, it is true that research neglects women's crops. Furthermore, as Schroeder (1997b) argued, the way women grow vegetables is often regarded as unprofessional and backward by many agents of NGOs and national and international institutions. Moreover, national and international institutes often neglect (although less so nowadays than in the past) post harvest traits like taste, cooking quality, milling quality, storing quality etc during the development of new varieties.

This would be one explanation why women seem to maintain diversity, because they consider a different, and sometimes wider, range of traits important, compared to men. Because women usually are responsible for processing and cooking, they need, and consequently conserve, a wide range of varieties and crops (Worede and Mekbib, 1993). In research conducted by Bellon *et al.* (2003) the maize varieties most often chosen by men belong to more agro-morphological groups (4 groups in total) than the maize varieties chosen by women (belonging to 2 groups). How much diversity the most popular choices of men and women actually represent is not explained in the article, unfortunately. What is interesting is that the most popular varieties chosen by men and women were different in 6 out of 10 cases (Bellon *et al.*, 2003). Research on sweet potato in South Africa also showed that, within the same compound, men and women sometimes have different variety preferences (Nuijten, unpublished). In Zimbabwe men and women prefer different varieties of sorghum (Van Oosterhout 1993). These differences are quite logical because men often emphasise traits that are important for the suitability of the produce for sale, while women often emphasise traits that are related to food preparation.

In certain areas women might also need a larger set of varieties because they are farming under more marginal and diverse conditions than men. As earlier mentioned, Guyer (1984) argued that technical innovations are seen as a vehicle for, and a consequence of, attempts by different groups within a community to exert control over the production process. In Zimbabwe, a new technology (inorganic fertiliser in combination with organic fertiliser), is predominantly used on men's crops, which are also cash crops, grown on the best fields, leaving women to grow subsistence crops on poorer soils without inputs (Van Oosterhout, 1996). As indicated in Chapter 1, higher levels of diversity often occur under marginal cultivation conditions and for subsistence crops compared to cash crops. Since women are responsible for both the cultivation and preparation of the food in Zimbabwe, it is likely that this also has a positive effect on food crop diversity. In short, it is because of a complex of economic, socio-cultural and environmental conditions that women in Zimbabwe care more about crop diversity than men do.

In the case of maize in southwest China seed and variety management, together with farming in general, has shifted towards the women's domain because men have gone to the urban areas to look for work (Song and Jiggens, 2003). The same pattern is visible in the case of potatoes in Peru (Zimmerer, 1991). Boserup argues that in African farming systems women play a bigger role due to colonial capitalism (1970). Hence, it could be argued that the expansion of capitalism actively created a sexual division of labour where it did not necessarily exist before (Guyer, 1980). This shows how technical innovations, such as changes in crop repertoire, are a vehicle for attempts by different groups within a community to exert control over the production process (Guyer, 1984). As mentioned in Chapter 2, it might also be possible that after the introduction of a new technology women are among those groups who first lose influence and control within a community first, but that over time they are also able to regain their lost influence and control.

Because in many cropping systems women play a bigger role than men, it is also logical that they play a larger role in seed and variety management. It is also mentioned by Howard (2003) that seed selection and variety management is in the woman's domain. This is so in the case of rice in Southwest Casamance (Linares, 1981), in the case of beans in Rwanda (Sperling, 1992; Sperling *et al.*, 1993), and in the case of rice in the Garhwal Himalaya region of India (Shiva and Dankelman, 1992). The last case, however, also mentions a clear skewed labour organisation, in which men work 1212 hours per year in agriculture while women work 3485 hours per year (Shiva and Dankelman, 1992). Unfortunately, such case studies only discuss one crop, not giving much information about seed handling of the other crops in that farming system, making it difficult to have a complete overview on the exact roles of men and women. Whereas a positive relationship between crop diversity and women in Rwanda was suggested by Sperling and Loevinsohn (1993), such relationship was not found in Zimbabwe (Cromwell and Van Oosterhout, 1999). A possible explanation is that, as more children attend school nowadays, workloads for women have increased and as a result they grow smaller farms than before (Cromwell and Van Oosterhout, 1999). Another explanation was mentioned above, i.e. that the picture available of the cropping system in Rwanda is incomplete.

Other case studies suggest that seed and variety management is regulated in variable and complex ways. In the case of maize in Mexico it is both men and women who are involved in seed selection - men select superior plants in the field, while women select superior ears during cooking (Rice *et al.* 1998). In Peru cassava is a women's crop, but the (male) shamans play a crucial role in cassava variety management and development (Salick *et al.*, 1997). In rice farming in central Siera Leone men and women are both involved in variety management and development (Richards, 1986). In Northern Sierra Leone, however, it appears that often only men are involved in seed purification (Jusu, 1999).

'Women and Plants' (Howard, 2003) offers several case studies which explained that women deal with and have extensive knowledge of crop diversity, genetic diversity or both, and that this knowledge is more extensive than among men. These case studies show that women's involvement with plants reflects a range of social, cultural, economic and political structures and influences. This makes it difficult to compare the behaviour of men and women directly in regards to plants. Furthermore, it is very difficult to substantiate the idea of the superiority of women's plant knowledge if crops studied are only cultivated by women. Women may have more knowledge of a crop simply because of their exposure to that crop type. This is supported by Linares (1981) observing that in Casamance women have more expert knowledge about varieties because they are more involved in variety management, while men, who do the land preparation, have more expert knowledge about soils. It is for similar reasons that older people usually have more knowledge about agriculture than younger people.

What is not clear is whether women have a general affinity for plants. What we need are data for women and men working on the same crop and being both involved in seed management of that crop in the same culture and environment. What is attempted in this thesis is a closely controlled comparison of how men and women of the same compound cope with two crops with different breeding systems, backed by analysis of data on how men and women interpret the differences. We now turn to detailed comparison of men and women managing rice and millet in the same case study villages in The Gambia.

9.6 Genetic diversity and gendered knowledge in The Gambia

Farming practices and gender

In this section various aspects of rice and millet farming in The Gambia in relation to gender are compared and discussed in a cohesive way. After this section, the results are presented of a grouping exercise in which men and women were asked to group millet spikes and rice panicles.

Cultivation practices

In Chapter 3 the cultivation practices for rice and millet were described. Since both crops have a different phenology and plant structure, it is obvious that many of the cultivation practices will be very different. However, it is somewhat surprising that there is no correlation between the use of inputs in rice and millet. It is logical to expect that particular compounds use more inputs than other compounds. But it is somewhat surprising that if in a particular compound men use fertiliser in millet, it is no guarantee that the women of the compound will do the same and vice versa. The same is true for the use of sowing machines. The upper stretches of the transitional zone are well suited for mechanical sowing of rice. However, men are very reluctant to help their wives, or to lend them their sowing machines and donkeys. This brings out that rice and millet cultivation are two separate, rather independent production systems. It seems that men and women are quite comfortable in keeping it that way. Possibly, all of them know, as argued by Guyer (1984), that technical innovations can lead to attempts by different groups within a community to exert control over production processes. This might also explain why women are also reluctant to learn to work with animals and machines (see Baker, 1995), and why women are reluctant to harvest rice with a sickle instead of a small knife, which is viewed as a tool suitable for men but not for women. It might also explain why women say that walking with shoes in the rice fields has a negative effect on the yield and hence shoes are not allowed in their rice fields.

Variety management and number of existing varieties

In Chapter 7 it was argued that the breeding system of the rice and millet is one of the main reasons that more rice varieties exist than millet varieties. Chapter 5 showed why women need more rice varieties than men need millet varieties. Some factors that can explain the high numbers of rice varieties used by farmers are ecological complexity and larger number of variety criteria (see Chapter 5).

Another reason is that in those areas where rice cultivation is possible rice is the main crop grown by women. Women do grow other crops, but these are far less important than rice. Men, on the other hand, grow a variety of crops at the same time: millet, groundnuts or cassava, maize, and some other minor crops. So, whereas during the rainy season the average woman grows about 1.5 crops, the average man grows 4-5 crops (Table 9.1). In those areas where rice cultivation is not possible anymore, women grow millet, groundnuts and some other minor crops separately from men. And usually, just like men, they grow one variety of each of those crops. So, in those areas where rice cultivation is not possible, there are no clear differences in crop choice (except possibly cassava and fruit trees, cultivation of which depends on having land rights) and the number of varieties used. All this suggests therefore that the high number of rice varieties is not because women grow rice, but rather that a high number of varieties is typical for rice cultivation.

The larger number of crops grown by men can also be attributed to the larger male labour force, when compared to the female labour force (see Chapter 2). Even number of crops per person is greater for men than for women (Table 9.2). There is also a small positive association between labour availability and the number of crops grown by men (correlation = 0.285, p = 0,002; N = 120) but not for labour availability on crops grown by women. Instead, there is a small significant relation between labour availability and number of rice varieties grown by women (correlation = 0.193; p = 0.027; N = 131). In fact, it seems likely that the smaller number of crops grown per person for women compared to men is compensated by the rice varieties grown by women (Table 9.2). Unfortunately, male farmers were not asked how many varieties of groundnuts, cassava and other crops they grow, so an unambiguous comparison is not possible, but from fieldwork it is clear that usually farmers grow one or two varieties of each of these crops.

Table 9.1: Average number of crops and fruit trees grown by men and women in the various districts, combined with the percentage of women who are involved in gardening (data from 2002-questionnaire).

district	*men* # crops	# fruit tree species	*women* # crops	# fruit tree species	% doing gardening*)
Kombo	4.2 a	2.4 b	1.4 a	0.6	90 b
Foni	5.6 b	2.1 b	1.5 a	0.4	40 a
Kiang	3.7 a	0.8 a	1.2 a	0.1	40 a
Fuladu	5.5 b	1.3 a	2.0 b	0.6	80 b
total	4.7	1.9	1.5	0.5	70
p	0.000	0.000	0.005	ns	0.000
F-value	7.1	12.9	4.5	2.2	13.0

*) = mostly during the rainy season

One quite clear difference between men and women is that through the marriages outside their villages women have relatively easy access to new rice varieties. However, it is difficult to assess how much this determines a difference between men and women in terms of variety management, because it can also be argued that men do not look for new millet varieties given the smaller number of millet varieties available. The limited number of millet varieties seems also a factor explaining why farmers' nomenclature in millet seems less consistent than for rice. Consistency in rice nomenclature seems related to the frequency of seed loss: the less seed loss, the more consistent variety naming. Since there is less seed loss for millet than for upland rice it might be expected at first sight that variety nomenclature would be more consistent for millet than for rice. However, it is not. For millet, farmers seem not to fuss about the consistency of names because the total number of millet varieties they need to distinguish is rather small.

Table 9.2: Average number of crops per *dabadaa* and per person for men, and average number of crops and rice varieties per *sinkiroo* and per person for women (data from 2002-questionnaire).

	men # crops / *dabadaa*	# crops / person	*women* # crops / *sinkiroo*	# rice varieties / *sinkiroo*	# crops / person	# crops + varieties / person
respondents (N)	123	120	125	132	124	124
average	4.7	1.2	1.5	3.2	0.7	1.7
Std. deviation	2.09	1.03	0.84	1.63	0.81	1.42

Management of off-types and wild relatives

In Chapter 7 it was explained that it is easier for new varieties to develop in the field in rice than in millet. Whereas some women indicated they sometimes test strange off-types found in the field, some men indicated they do not test strange off-types of millet. For millet, clearly distinctive off-types are infrequent occurrences in the field because of its outbreeding nature and variation within seed lots. Whereas rice harvesting is done panicle by panicle enabling good plant observations, millet plants are first pushed to the ground, resulting in a jumble of plants, which makes observations of individual millet plants impossible. Furthermore, the number of women harvesting rice is smaller than the number of men harvesting millet, which means that rice harvesting is slower, facilitating the observation of strange off-types. Another difference between men and women is that women talk more readily about strange off-types than men, who only talk about strange off-types after being asking several questions about it. Men often also say that they are not as good as women in differentiating rice varieties. This suggests that selecting off-types and working with many varieties are regarded as women's activities, with which men perhaps do not want to be associated. One question that remains unanswered is whether in the past, before a clear gender-based division of labour developed, women harvested and selected seed in millet. This could help explain why women seem more eager to experiment with seed and varieties than men - i.e. they have a culture of experimentation based on an historical division of labour.

In Chapter 2 it was also explained that men sometimes plant millet seedlings they get from other farmers instead of using their own sowing seed. The explanation by men is that millet is very much the same. This could be interpreted as a lack of interest of men in the quality of seed. Genetic analysis in Chapter 10, however, shows that the various millet seed lots are actually very similar.

Under particular ecological conditions (i.e. the lower stretches of the transitional zone) women are very active in removing wild relatives of rice, while men are less concerned about removing weedy relatives of millet. The differences in the levels of wild relatives in the various rice ecologies and the corresponding keenness to weed out relatives suggests that primarily the level of wild relatives dictates farmers' management of it (women are as relaxed as men about weedy relatives where these relatives are less frequent).

Seed selection

Chapter 4 showed that farmer selection in rice and millet is rather similar and both men and women indicated that for them seed selection in rice and millet is basically the same. The observed differences are rather related to plant structure. Since millet is very tall, it needs to be pushed down to the ground (making a tangle of stems, leaves and spikes) in order to cut the spikes; in the case of late millet selection can take place only after removal of the bristles. For rice, large numbers of panicles are needed for sowing seed, and women apply negative selection, only removing diseased panicles and mixed-in varieties they really do not want in their sowing seed. Observing women during harvesting, and seeing the mixed-in varieties remaining in the bundles meant for sowing, does not give the impression of women as careful selectors. However, the harvesting of rice plants is done one by one, enabling observations and selection of off-types. If the panicle of an off-type gets in a bunch, it is because the woman harvesting has decided to let it.

Grouping exercise

From the above it follows that differences in variety management are related to various agronomic, socio-economic and cultural factors. Yet, during interviews men often mentioned they do not understand how women can distinguish all those different rice varieties and women sometimes complained that men just do not bother about variety testing and management. Hence, a small grouping exercise was set-up to test whether women are actually better in distinguishing varieties.

Because rice is grown exclusively by women and millet by men, men often do not know the exact names of rice varieties and women not the exact names of millet varieties. So, it was not possible to ask men and women to name various rice and millet varieties. Instead, men and women from Tujereng and Faraba were asked to group millet spikes and rice panicles based on the morphology of the spikes and panicles. In total, 11 men and 11 women from Tujereng and 10 men and 10 women from Faraba were asked to group 35 millet spikes and 30 rice panicles from different varieties. It was assumed that, since men actually do the work in the millet field and women in the rice field, men would be more accurate in grouping millet and women in grouping rice.[14]

Results for millet

Most people - both men and women - made two groups for millet, often calling them black and white millet. Some other people made three groups and a few made four groups (Table 9.3). In Chapter 6 it was explained that farmers in Faraba think there are more millet varieties than in Tujereng, but this does not clearly show in the results of this exercise.

Table 9.3: Number of groups that were made with the millet spikes by men and women from Tujereng and Faraba (N = 11 for Tujereng and N =10 for Faraba, for men and women).

	men			*women*		
# groups	Tujereng	Faraba	all	Tujereng	Faraba	all
2	6	5	11	7	6	13
3	4	4	8	4	3	7
4	1	1	2	0	1	1
Average	2.5	2.6	2.6	2.4	2.5	2.4

After grouping, the farmers were asked to name or describe their grouping. In total 14 different groups were identified, 7 groups were identified by both men and women, 4 by men only and 3 by women only (Table 9.4). The two most common groups are white and black. Table 9.4 also shows that different groups were identified in Tujereng and Faraba and that the groupings made by men and women were more consistent with each other within each village than were the groupings made by men from Faraba and Tujereng, and the women from Tujereng and Faraba. This shows that within each village there is a somewhat specific discourse on millet, not only among men of the same village, but also between men and women of the same village.

Further, the number of men and women allocating each spike to a specific group was analysed. If less than three men or women allocated the spike to a different group than the main group, it is considered as a very consistent grouping. If less than four men or women had allocated the spike to a different group, this is considered as a consistent grouping. Table 9.5 shows the number of millet spikes for which men and women from Faraba and Tujereng produced very consistent or consistent groupings. The results show that in Tujereng the grouping was more consistent than in Faraba, and that women produced more consistent groupings than men. In Tujereng fewer strangers were asked to participate compared to Faraba, which partly explains the difference between Faraba and Tujereng. The village of Faraba as a whole has more strangers than Tujereng (see Chapter 2) and in general farmers in Faraba think there are more millet varieties than in Tujereng (see Chapter 6). Village discourse in Faraba on millet varieties is more diverse than in Tujereng, because strangers come from various areas with different varieties, and have often changed varieties when moving to Faraba.

[14] During the grouping men complained that we should not ask them to group rice panicles, and women likewise complained they did not know anything about millet and therefore claimed they could not group the millet spikes.

Table 9.4: Number of millet spikes allocated to groups by men and women of the villages of Tujereng and Faraba.

group	name of millet group	men Tujereng	Faraba	all men	women Tujereng	Faraba	all women
	# respondents	11	10	21	11	10	21
1	completely white	6		6			0
2	light white			0	7		7
3	white	118	123	241	180	116	296
4	different white	5		5		27	27
5	majo	29	35	64			0
6	black & white on one spike	2		2	4		4
7	different black[1)]	16		16			0
8	different black			0	6		6
9	black	188	106	294	175	140	315
10	komba		58	58		27	27
11	dark black		14	14	5	23	28
12	big seeds			0		6	6
13	Kiang		7	7			0
14	suno	16	4	20		10	10

[1)] The spikes allocated to groups 7 and 8 were different.

It is also interesting to note that two extremely big, impressive spikes with a mixed seed colour (both black and white) were classified by most men as black, whereas 50% of the women classified them as white, and 50% as black. The average size of the spikes classified as black millet (group 9, Table 9.4) was also slightly greater for those spikes grouped by men than those grouped by women. The reverse is also visible. The average size of the spikes classified as white millet (group 3, Table 9.4) was slightly smaller for those spikes grouped by men than those grouped by women. This suggests that women did the grouping mostly based on qualitative traits, mainly seed colour, whereas men also considered the size of the spikes whether to call them white or black. Earlier observations also showed that men from Tujereng would include impressive spikes with white seed to their seed stock consisting of black millet. In Faraba the majority of men also grow black millet. Women, instead, focus more on qualitative traits to distinguish off-types of rice when selecting seed.

Table 9.5: Number of millet spikes (out of 35) for which men and women from Tujereng and Faraba (n = 21) did a consistent or very consistent grouping.

Village	# men and women	# spikes grouped by men		# spikes grouped by women	
		very consistent [1)]	consistent [2)]	very consistent [1)]	consistent [2)]
Faraba	10	0	7	1	15
Tujereng	11	10	14	27	29
All	21	0	0	0	8

[1)] = # spikes for which less than three people did inconsistent grouping
[2)] = # spikes for which less than four people did inconsistent grouping

Results for rice

For rice, a similar exercise was conducted with 30 panicles of 15 *O. sativa* varieties, 2 *O. glaberrima* varieties and 4 *O. sativa* off-types. Varieties that do not shatter their seeds easily were used. For that reason more varieties cultivated in Tujereng were used than in Faraba. Non-shattering varieties were chosen to avoid a situation in which people at the start of the grouping experiment would do a different grouping than the people at the end of the experiment because the appearance of the panicles changed as more seeds were shaken loose in handling.

Table 9.6 shows that, for rice, both men and women make more groups than they do for millet and that the number of groups per informant varies a lot, from 4 up to 21. Women make slightly more groups of rice than men (not significant with Student's t-test). There is no clear difference in the number of groups of rice panicles between Faraba and Tujereng.

Table 9.6: Average number of groups of rice panicles made by men and women from Faraba and Tujereng.

	village	respondents (N)	average # groups	std. deviation	minimum	maximum
men	Faraba	10	9.2	5.16	4	19
	Tujereng	11	10.2	4.94	5	18
	total	21	9.7	4.94	4	19
women	Faraba	10	12.1	5.32	4	20
	Tujereng	11	11.9	4.46	6	21
	total	21	12.0	4.76	4	21
total	Faraba	20	10.7	5.31	4	20
	Tujereng	22	11.0	4.67	5	21
	total	42	10.9	4.93	4	21

The analysis undertaken to understand the consistency of the millet grouping was not done for rice, since the grouping of rice panicles was far more diverse. Instead, I made a standard grouping of the varieties based on their morphological similarities (each group thus containing several similar varieties) and the grouping of the farmers was compared to that standard. Each variety corresponding to my grouping got one point, and the total number of points was added. This means that 30 points is the maximum score. The average, minimum and maximum scores are shown in Table 9.7. Overall, women got a higher score ($p = 0.001$ with Student t-test) than men, but the differences were not significant when men and women of each village were compared. The scores for the people from Tujereng were slightly higher than those for the people from Faraba, which can be explained by the fact that the people from Tujereng were more familiar with the rice material (more varieties suitable for testing – i.e. non shattering – came from Tujereng). This indicates that there is a learning aspect in differentiating rice varieties. Furthermore, the minimum and maximum scores indicate that there is huge variation in grouping capacities between individuals of both genders. Some men from Tujereng were almost as accurate in grouping as certain women.

It was also interesting to see that a good number of both men and women grouped the *O. glaberrima* varieties together with *O. sativa* varieties. Apparently *O. glaberrima* is easily confused with *O. sativa*, which means that *O. glaberrima* will be easily mixed up in the sowing seed and in that way survive.

Table 9.7: Average scores men and women from Faraba and Tujereng got for grouping rice panicles.

	village	respondents (N)	average score	std. deviation	minimum	maximum
men	Faraba	10	14.3	2.31	10	17
	Tujereng	11	15.3	4.63	10	23
	total	21	14.8	3.66	10	23
women	Faraba	10	17.1	2.81	12	20
	Tujereng	11	21.3	4.31	12	26
	total	21	19.3	4.17	12	26
total	Faraba	20	15.7	2.89	10	20
	Tujereng	22	18.3	5.34	10	26
	total	42	17.0	4.49	10	26

9.7 Discussion of the group experiment

The results of the grouping experiment suggest that gender does not play a clear role in variety management practices. Men and women differentiate similar numbers of groups with the millet spikes and rice panicles. The grouping of millet spikes shows that women do a more uniform grouping than men, but the grouping of rice panicles shows that accuracy among women also varies a lot. The data suggest that women have a somewhat keener eye to differentiate varieties than men, but do not support a hypothesis that there is a categorical difference in the ability of men and women to recognise and differentiate rice and millet varieties. The somewhat keener eye of women may, in fact, be age-related. The experiment was undertaken among married couples, which means that men, on average, were considerably older than the women and eye sight deteriorates with age. Women need to differentiate rice varieties continuously (due to farming practices), in that way training themselves in differentiating varieties, whereas for men, there is less need to acquire an ability to differentiate millet varieties. This appears to sustain a general perception that women are better at varietal recognition than men, but experimentation on grouping produced less clear distinctions than might have been expected.

The grouping of the millet spikes indicates that women did the grouping based on the appearance of the spikes, while men used morphological information perhaps reflecting knowledge of varieties. This distinction did not show up in the rice grouping, which might be explained by the fact that the diversity in rice panicles is not continuous whereas variation in millet spikes tends to be more continuous. This means that a rice variety can be more clearly defined on its traits and therefore is more generally recognised, whereas the definition of a millet variety is less clear and thus less readily recognised as a discrete variety.

The grouping exercise also shows that group dynamics plays a role in selection practices, although the exercise was conducted with individuals. Men and women of the same village did the grouping of millet in a similar way, while the groupings showed (small) differences between the two villages.

Possibly the most important conclusion to be drawn from this experiment is that, whereas men suggested that they cannot differentiate rice varieties as well as women, in reality there is no clear difference between the genders. This suggests that claiming or denying capacities in relation to varietal differentiation is more part of gender identity than something based on skill.

Perhaps we should be cautious about general claims that seed selection and variety management belong to the woman's domain. For each situation one should ask more specific questions about who is responsible for seed selection and variety management in order to understand which groups might be involved in 'local' seed system improvement.

9.8 Conclusions

This chapter indicates:

- Little evidence that skill in differentiating rice and millet varieties is strongly gendered.
- Differences in variety and seed management are mostly determined by socio-economic and agronomic factors.
- Where there is perceived difference between men and women in variety differentiation exchange is an aspect of gender identity rather than skill.
- On balance it seems that what women and men know about rice and millet in The Gambia reflects their different learning experiences working with two crops in which variety presents itself differently.

- Some men and women are more skilled and motivated when working with plants than others.
- This study has uncovered no evidence that women are, in general, better at seed selection and management because of a gender-based orientation to caring or nurturing.
- It may be argued that caring about diversity is a feminine trait shared by both men and women. This explains why women are often considered better in observing and dealing with crop diversity than men.

10 Genetic diversity at village level[15]

10.1 Introduction

In low-input farming systems farmers often use a wide range of crop varieties to provide harvest security, yield stability and the possibility to adapt to changing ecological conditions (Hardon and De Boef, 1993; Teshome *et al.*, 1999). Farmers in these farming systems adopt formal varieties only to a limited extent, or do not adopt them at all. The main reason for not adopting formal varieties is that they do not meet farmers' requirements. In recent years, various Participatory Plant Breeding initiatives have been set up to develop varieties that meet farmers' requirements better (Almekinders and Elings, 2001; Sperling *et al.*, 2001). Some of these initiatives aim to collaborate with farmers in very early stages of crop development, with the breeder acting more as a facilitator providing the raw genetic material. It is suggested that farmers maintain high levels of crop diversity through developing new varieties and by matching specific varieties to particular conditions. How much genetic diversity these varieties represent, however, has not often been studied and different processes seem to regulate the amount and development of genetic diversity in crops in low-input farming systems. Rather than continuing to assume that the obvious morphological diversity of farmer varieties assures a broad genetic base on-farm, diagnostic surveys of genetic variation and genetic distance between varieties are urgently needed (Wood and Lenné, 1997).

The focus of this chapter is on assessing genetic diversity at crop level (by comparing variety pools of several villages) and not at individual variety level (i.e. within varieties). Two main processes can be identified regulating genetic diversity in farming systems. As the result of one process farmer varieties look very diverse morphologically, but are actually genetically uniform because of continuous selection on qualitative traits in the same gene pool (Cox and Wood, 1999) and because most farmer varieties are derived from genetic recombination of existing farmer varieties (Wood and Lenné, 1997). A second process, however, maintains genetic diversity in the 'local gene pool' through mutation, introgression from wild and weedy relatives, hybridisation between varieties and the introduction of new landraces or formal varieties (Almekinders *et al.*, 1994; Almekinders and Elings, 2001). It has sometimes been argued that the introduction of formal varieties halts this process in it tracts, and thus reduces genetic diversity in farming systems (Altieri and Merrick, 1987; Ceccarelli *et al.*, 1992). Modernisation of agriculture tends to replace large numbers of farmer varieties with small numbers of formal varieties (Cooper *et al.*, 1994).

An issue arising is whether formal or farmer varieties represent higher levels of genetic diversity. It is often assumed by plant breeders that formal varieties represent more genetic diversity than farmer varieties since plant breeders have access to world-wide genetic resources, whereas farmers do not (Smith, 2000). An example often mentioned is the genetic background of the variety IR 64, based on 20 varieties (Dalrymple, 1986). This leads to the assumption that formal varieties increase genetic diversity in low-input farming systems. However, it is also common practice in breeding programs to continue breeding with a limited range of elite materials, forming a narrow gene pool (Rasmusson and Philips, 1997). This leads to an opposite assumption that farmer varieties represent much more diversity than formal varieties because the genetic base of formal varieties has been greatly narrowed. If farmer varieties are replaced by formal varieties, genetic diversity in farming systems will be reduced (Chang, 2003). It is perhaps worth noting that in the case of IR 64, of the 20 varieties four contribute 65% to its

[15] This chapter is submitted in an adjusted form to Genetic Resources and Crop Evolution with Rob van Treuren, CGN the Netherlands, as co-author.

genetic background (cf. Dalrymple, 1986). Similarly, in the case of North American soybean 6 ancestors (of a total of 80) constituted more than half the genetic base of 258 cultivars released between 1947 and 1988 (Witcombe, 1999). A fog of contrasting assumptions thus obscures the issue of whether science or traditional agriculture is better at keeping plant genetic resources in play.

A factor complicating any analysis of genetic diversity in traditional farming systems is that different farmers may use the same name for different varieties or use different names to indicate the same variety (see Chapter 6). Morphological analysis is often used to analyse genetic diversity, but only visual traits are assessed. To offer a better diagnosis for which Wood and Lenné (1997) have called we must turn to molecular methods. Molecular analysis assesses the hidden genetic diversity, complementing morphological analysis. This chapter presents data based on morphological and molecular analyses of genetic diversity at village level found in upland rice and millet.

Morphological and molecular data were used to identify homonyms and synonyms among locally-named varieties and to analyse between village levels of diversity for both crops. This implies understanding which varieties can be found in which villages and analysing how much are these varieties genetically similar. For rice, the data were also used to compare genetic diversity represented by formal and farmer varieties and to compare old with new farmer varieties. Such comparisons were not possible for millet because no formal varieties of late millet are used by farmers in The Gambia (Chapter 5) and because information from farmers did not allow differentiation between new and old farmer varieties of late millet. Because millet is an outbreeder, and genetically diverse at the population level, it was also investigated whether seed lots of the same millet variety used at different geographic locations have differentiated between villages as a result of local adaptation.

10.2 Materials and methods

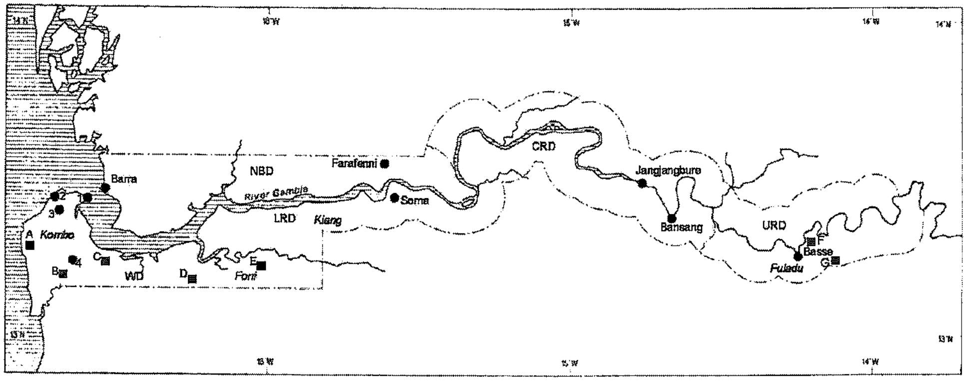
Study sites

In the western part of The Gambia four villages (Tujereng, Kitti, Faraba and Janack) situated at intervals of 20–30 km in a line from west to east were chosen as study sites (Figure 10.1). As primary site Tujereng was chosen, because in this village governmental and NGO involvement in variety management was very low, which provided a good basis for a study on traditional farmer variety management. The main criteria for the three other villages were that late millet and upland rice were cultivated and that they were situated more or less equidistant from each other. For millet, three additional villages (Sangajor, Damfakunda and Sanending) were also included in the study to enable a better understanding of the effect of geographical location (Figure 10.1). Damfakunda and Sanending were in the extreme east of The Gambia in Upper River Division.

Morphological analysis

<u>Study material</u>

In this study the term 'farmer varieties' is used to indicate traditional varieties, often denoted as landraces. Based on information from farmers, the farmer varieties were divided in four groups (Table 10.1). Those where the time of adoption by farmers was known were denoted as either new or old farmer varieties. The new farmer varieties were adopted by farmers during or after



● Major town
■ Research site
1 Banjul (Capital)
2 Bakau
3 Serrekunda
4 Brikama

A Tujereng
B Kitti
C Faraba
D Janack
E Sangajor
F Damfakunda
G Sanending

WD Western Division
NBD North Bank Division
LRD Lower River Division
CRD Central River Division
URD Upper River Division

0 25 50 miles
0 25 50 km

Figure 10.1: Location of the study sites.

the decrease in rainfall in the early 1970s. A third group consisted of varieties where the time of adoption was unclear and these are described as 'other farmer varieties'. The fourth group of farmer varieties consists of old farmer varieties not cultivated anymore but still present infarmer varieties as off-types. The formal varieties[16] are divided in two groups. The first includes all formal varieties cultivated by farmers and the second includes those formal varieties recommended for farming, but not adopted by farmers in the study area. For millet, the only terms used are 'farmer varieties' and 'formal varieties'.

Per rice sample, 0.5 kilo of panicles (about 300 panicles) was taken at random from the harvest as a representative sample of a variety. Based on farmers' descriptions of the morphological features of varieties, each rice sample was carefully cleaned. Among cleaned material, 13 off-types were found morphologically different from any of the collected varieties. Nine of these off-types were included in the study, of which four were identified as old farmer varieties not cultivated anymore, one as segregating material and four as unknown material. From the four villages a total of 74 rice samples (both formal and farmer varieties) were obtained. The aim of the sampling was to obtain as many upland varieties as possible grown in the four villages (in the event about 85 - 95% was collected). The varieties collected in Tujereng represented about 95% of all upland varieties grown in Tujereng, while the varieties collected in Kitti represented only about 85% of all upland varieties grown in Kitti. The percentages for Faraba and Janack were between 85 and 95%. The reasons that not all varieties were collected are that a) the farmer growing a particular variety had not harvested it yet, b) the farmer was reluctant to give us a sample, c) the farmer had already threshed the harvest of that variety, or d) we had already obtained several samples from that farmer and did not want to ask too many. Furthermore, in Kitti we did not meet many farmers in their fields. For varieties of which it was very clear that we already had one or several samples, we stopped collecting that variety: for example, if a farmer mentioned she got the seed of a particular variety from a farmer we had interviewed before and from whom we had already obtained a sample of that variety. It is important to stress the aim of collection was to obtain a good range of all varieties grown locally. But samples do not represent proportional genetic diversity within farmers' fields.

[16] The term 'formal varieties' is used instead of modern varieties because a number of formal varieties were already developed and released in the 1960s (Appendix 5).

Based on information from NARI-researchers and literature (Gupta and Toole, 1986; FAO, 2001), a total of 20 formal varieties was obtained from the National Agricultural Research Institute (NARI), the Centre de coopération Internationale en Recherche Agronomique pour le Développement (CIRAD), the Institute Senegalese de Recherche Agronomique (ISRA) and the West African Rice Development Association (WARDA). The formal varieties included both varieties released in the past and recently developed varieties tested in the village of Tujereng in 1998. Two of the formal varieties are so-called Nerica (New Rice for Africa), derived from interspecific hybridisation between the *Oryza* species *sativa* and *glaberrima*. Formal varieties were also included in the study to establish which of them are presently grown by farmers. Due to renaming by farmers this cannot be determined by inventory of variety names alone. Formal and farmer varieties were all *Oryza sativa* varieties. In addition, four samples of *O. glaberrima* (found as off-types within the samples) were included as an outgroup to evaluate differences within *O. sativa*.

For millet, a total of 17 samples, representing four varieties, were collected from seven villages. In addition, a late millet variety from ISRA, improved through bulk selection, and two late millet varieties from the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) were included in the study. These were the only formal late millet varieties that could be found.

Table 10.1: Numbers and groups of rice varieties used for the various analyses.

	total # samples sown in the trial	comparison between villages (# samples)	Comparison of farmer and formal varieties (# varieties)	AFLP analysis (# varieties)
farmer varieties	36	29	20	20
new farmer variety	18	13	6	6
old farmer variety	10	8	9	9
other farmer variety	8	8	5	5
old farmer varieties not cultivated anymore found in samples collected from farmers	5	-	4	4
formal varieties	39	16	27	28
from institutes, recommended for cultivation	20	-	16	16
from farmers	19	16	11	12*)
unclear status	7	7	7	7
O. glaberrima	5	4	4	4
O. barthii	-	-	-	2
off-types	7	-	-	8**)
reference varieties				4
materials from Jusu (1999)				6
total	99	56	62	83

*) One variety (*Mani Suntungo*) consisted of a mixture of 2 varieties which were separated for AFLP analysis
**) An off-type was separated from the variety *Mani Wulendingo* at the end of the field trial

Lay-out of field trials

Both rice and millet trials were conducted in farmers' fields in Tujereng under researcher management in 2002. For the rice trial, a forest area was slashed and burned. Compound fertiliser (NPK) was applied at a rate of 25:25:25 kg/ha, followed by ploughing of the trial. Only a single fertiliser treatment was given in order to replicate farmers' practices as much as possible and to avoid excessive lodging of farmer varieties. The trial consisted of 4 replications in which each plot consisted of 2 rows of 3 m spaced 30 cm apart. The distance between plants within rows was approximately 10 cm. Tall and short varieties were sown in separate groups within each replication to avoid shading effects. Different samples with the same panicle morphology were randomised and sown adjacently in groups within each replication in order to establish whether they belonged to the same variety. These groups were randomised within each replication.

The millet trial was located in a field which had been left fallow for five years. Prior to ploughing, compound fertiliser (NPK) was applied at a rate of 40:40:40 kg/ha to ensure good soil fertility. The trial was sown in a completely randomised block design with 4 blocks, with plots of 6 by 3.5 m, each consisting of 5 ridges. The distance between ridges was 70 cm and between plants about 80 cm.

Measured traits

Morphological traits of rice and millet were measured following the guidelines of IRRI (1996) and IBPR/ICRISAT (1993) respectively. The measured traits are shown in Tables 10.2 and 10.3 for rice and millet, respectively. Because of soil variation in the rice trial, one replication was excluded from measurement. For all rice and millet samples, 6 plants per replication were measured, yielding 18 measurements per sample for rice and 24 for millet.

Statistical Analysis

For both rice and millet, plot averages were used for analyses. For rice, principal component analyses (PCA), using SPSS, were performed to compare genetic diversity between villages and between farmer and formal varieties. For millet, the cluster analysis performed was based on euclidean distance measures, using Genstat. Some of the millet samples did not set seed because of pests and diseases, and consequently plot yield, 1000 seed-weight and 1000-seed volume were excluded from the analysis. For the quantitative traits of millet, ANOVA and Duncan's multiple comparison test were used to analyse which varieties differed significantly for which traits.

Molecular analysis

Study material

For the molecular analysis of rice, the same varieties used for the comparison between formal and farmer varieties (see above) were used. In addition, some extra materials were studied, including the four off-types of unknown origin found in farmer varieties (see morphological analysis), two off-types found in the field trial in two varieties, and two samples of *O. barthi* as an extra outgroup next to *O. glaberrima* (Table 10.1). In 2003, approximately 20 seeds were sown in a greenhouse from each of 65 accessions of *O. sativa*, four accessions of *O. glaberrima* and two accessions of *O. barthii*. For each accession, equal quantities of leaf material were collected from 10 randomly chosen, two-week-old seedlings that were combined together into a single sample (~100 mg). In addition to bulked sampling, five individual plants from one of the *O. glaberrima* accessions and a black-husked accession of *O. barthii* (*O. barthii* black) were separately sampled in order to allow testing of homogeneity of accessions. DNA samples obtained in earlier studies were added as references to the study material. These were DNA samples from the formal rice varieties IR36, IR66, RC10 and RC18 (Bertuso *et al.*, 2005) and DNA samples from six farmer rice varieties from Sierra Leone (van Treuren, unpublished). Of the farmer rice varieties from Sierra Leone, three varieties were described as interspecific hybrids between the species *sativa* and *glaberrima* (Jusu, 1999). Two separate leaf samples were also collected from each of two mature plants derived from an interspecific hybrid between *O. sativa* and *O. glaberrima* found in the trial. These samples were included to extend the number of entries with interspecific origin and to allow verification of the reproducibility of

AFLP fingerprinting profiles. Tissue samples were collected in 2-ml Eppendorf tubes, immediately frozen in liquid nitrogen and stored at –80 °C upon return to the laboratory. DNA isolation basically followed the procedures described by Fulton *et al.* (1995). In total, 95 rice DNA samples were used for AFLP fingerprinting.

Table 10.2: Measured characteristics of upland rice.

characteristics	scale
vegetative	
plant height	in cm, from soil surface up to the tip of the tallest panicle
leaf length	leaf below flag leaf, from collar to tip of leaf
leaf width	leaf below flag leaf, widest portion of the leaf
ligule length	mm, from the base of the collar to the tip
basal sheath colour	at basal portion of the main culm
leaf angle	angle of openness (1 = erect, 5 = horizontal, 9 = droopy)
inflorescence	
panicle length	in cm, from panicle base to tip, main panicle
husk colour	0 = straw, 1 = gold and gold furrows on straw background, 2 = brown spots on straw, 3 = brown furrows on straw, 4 = brown (tawny) ,5 = reddish to light purple, 6 = purple spots on straw, 7 = purple furrows on straw, 8 = purple, 9 = black, 10 = white
husk pubescence	1 = glabrous, 2 = hairs on lemma keel, 3 = hairs on upper portion, 4 = short hairs, 5 = long hairs (velvety)
grain length	main panicle, in mm, length from base of lowermost sterile lemma to tip of fertile lemma or palea
grain width	main panicle, in mm, measure grain at widest point
100 grain weight	weight of 100 seeds (well-developed)
seed coat colour	1= white, 2 = light brown, 3 = speckled brown, 4 = brown, 5 = red, 6 = variable purple, 7 = purple
agronomic	
culm number	number of culms with heads
50% flowering	number of days after sowing to 50% flowering
threshability	assessed via hand threshing, from 1 to 9 (1 = easy to thresh, 9 is difficult to thresh)

Table 10.3: Measured characteristics of millet.

characteristics	scale
vegetative	
plant height	in cm, from ground level to tip of spike
leaf length (ear leaf)	in cm, leaf on 4th node below the head
leaf width	in mm, leaf on 4th node below the head
separation	in cm, distance between two successive leaf blades, 3rd and 5th leaf from the top of the main culm, divided by 2
stem diameter	in mm, between 3rd and 4th node from the top of the main culm
inflorescence	
spike length	in cm, from base to tip, main spike
spike thickness	in mm, widest portion, main spike
length of bristles	3 = short, bristles below level of the apex of the seed, 5 = medium, bristle between 0 and 2 cm above the seed, 7 = long, bristle longer than 2 cm above the seed
bristle colour	1 = green; 2 = tan tips; 3 = light red; 4 = red; 5 = purple
spike shape	1 = cylindrical, 5 = candle
seed colour	% black seeds (assessed before sowing)
agronomic	
tillering ability	# culms / plant carrying spikes
nr of nodal tillers	3 = few; 5 = intermediate; 7 = many
50% flowering	number of days after sowing to 50% flowering

For millet, approximately 60 seeds from each of 8 accessions were sown in the greenhouse, and about 100 mg of leaf tissue was collected from randomly chosen, two-week-old, individual plants. In addition, a single plant from each of two accessions was sampled twice. These four samples were used in a pre-screening to select suitable AFLP primer combinations to be used for the total sample and to allow reproducibility testing of the AFLP fingerprinting profiles. After tissue collection, experimental procedures and DNA extraction followed those described for the rice samples. DNA was extracted from 24 individual samples per accession, except for seed lot 7 represented due to poor germination by 19 individuals.

AFLP fingerprinting

AFLP analyses basically followed the procedures described by Vos *et al.* (1995). PCR products radiolabelled with P^{33} were separated by polyacrylamide gel-electrophoresis. The rice samples were analyzed for the *Eco*RI primer E13 (E-AG) in combination with each of the *Mse*I primers M49 (M-CAG) and M51 (M-CCA). These two primer combinations were found appropriate primer combinations for AFLP analysis in rice in an earlier study (Bertuso *et al.*, 2005). For millet, a pre-screening of 4 DNA samples was performed using 18 different primer combinations. *Eco*RI primers E12 (E-AC) and E13 (E-AG) were tested in combination with each of the *Mse*I primers M49 (M-CAG), M51 (M-CCA), M55 (M-CGA) and M61 (M-CTG), and *Eco*RI primers E32 (E-AAC) and E38 (E-ACT) were tested in combination with each of the *Mse*I primers M49 (M-CAG), M51 (M-CCA), M52 (M-CCC), M54 (M-CCT) and M55 (M-CGA). Based on sufficiently clear and reproducible AFLP polymorphisms, the primer combinations E32/M49 and E32/M54 were selected for AFLP analysis of the total sample of millet.

Data analysis

AFLP fragments in the range of 50-500 base pairs were scored manually for the presence or absence of bands on the autoradiograms. AFLP fragments that differed in size were assumed to represent different loci, each locus potentially having two alleles, i.e. presence and absence of a band. For rice, a total number of 134 bands was scored of which 92 were found to be polymorphic. For millet, 70 polymorphic bands were observed among the 100 bands scored. To compare the rice samples, Jaccard's similarity coefficients were calculated and a cluster analysis was performed using the UPGMA (unweighted pair-group method, arithmetic average) method. These analyses were performed using the NTSYS-pc software package (Rolf, 1993). For millet, genetic relationships between the varieties were calculated using Nei's unbiased estimate of standard genetic distance (Nei, 1987) and were represented by a dendrogram using the UPGMA clustering algorithm. These analyses were carried out using the software package TFPGA (Miller, 1997). Shannon's information index (Vom Brocke, 2001) was used to describe the level of variation based on molecular data between groups of rice varieties and within millet varieties. The more polymorphisms and the more equal the ratio between presence and absence of bands per polymorphism, the higher is the value of the Shannon's information index. The maximum value is 0.69. The formula of Shannon's information index is:

$$H = - \sum [f_i \ln f_i + (1-f_i) \ln (1-f_i)] / n$$

f_i is the frequency of the AFLP band at the i^{th} locus in a population and n is the total number of marker loci. Monomorphic markers were not excluded from the data set.

10.3 Results

Homonyms and synonyms

Because farmers often use different names for the same variety, or use the same name to indicate different varieties, it is difficult to determine which varieties are actually grown by farmers based solely on variety names. Morphological and molecular data were therefore used to identify homonyms and synonyms.

Rice

Based on morphological and molecular comparison, a very different picture emerged on variety use and distribution of rice than when variety names were compared (Table 10.4). When comparing the total number of identified varieties (38) with the total number of given variety names (49), the percentage of identified varieties was only 80% of the total number of variety names given by farmers. The number of identified varieties per village was on average 89% of the number of variety names per village belonging to the samples given by the farmers. This percentage ranged from 73 to 110% per village, indicating that variety names can lead to both under and overestimation of the actual number of varieties cultivated.

Some varieties were grown in more than one village, while other varieties were grown only in a single village. In particular Tujereng and Janack displayed a relatively large number of 'unique' varieties, while Faraba and Kitti did not. In Table 10.4 it is also indicated which varieties are formal varieties and which are farmer varieties. This distinction was not clear for 7 varieties, subsequently labelled with 'Unclear Status'. In all villages, except Tujereng, both formal and farmer varieties were grown.

Table 10.4: Status and farmer names of rice varieties sampled in Tujereng, Kitti, Faraba and Janack (numbers in between brackets mean that a variety is identified in a particular village in 2002 but not sampled in 2000). Samples indicated with 'CCA? (lot xx)' greatly resemble the variety CCA, but are different for one or two traits.

variety	status[1]	Tujereng	Kitti	Faraba	Janack
Kari Saba	FV	Kari Saba Mani Wulengo	Barafita Barafita Wulengo	Ablie Mano	Ablie Mano
Barafita Koyo	FV	Jokadou Mano	Barafita Koyo	Ablie Mano Sanyang Mano	(1)
Kumoi	FV	(1)	Mani Wulengo Mani Wulendingo Joko Mano	Mani Wulengo	
Binta Sambou	FV	Binta Sambou Mani Tereyengo Mani Koyo	Tujereng Mano	Mani Koyo	
Mani Suntungo	MV		Suntungo	Mani Suntungo	Bajiran
Peking	MV				Peking
CCA? (lot 29)	MV				Peking
CCA? (lot 31)	MV		Chinese Mano		
CCA? (lot 33)	MV				Derisa Mano
CCA? (lot 34)	MV			Peking	
CCA? (lot 36)	MV		(1)	Baraso	Kabili
Rasi	MV		Peking	Baraso Mani Suntungo Bolongkong Mano	
Terfatch	MV		(1)	(1)	Terfatch Mani Mesengo
Foni Mano	US	Foni Mano	(1)		
Akacha	US		Akacha		
Teiba	US			Teiba Mani Koyo	

variety	status*)	Tujereng	Kitti	Faraba	Janack
Chinese red	US			Chinese red	
Moti	FV				Kumoi
Tensi	FV				Tensi
Mani Tima	FV				Mani Tima
Tombom Mano	FV				Tombom Mano
Wesiwes (Wab ...) [1)]	MV				Wesiwes
Kadi Dabo (Se 302G?)[1)]	MV				Kadi Dabo
Kukone	US				Kukone
Bonti	FV	Bonti			Bonti
M Wulendingo	FV	Mani Wulendingo Mani Mesengo			Indingdingo
Kukur	FV	Kukur			
Muso Noringo	FV	Muso Noringo			
Sefa Koyo	FV	Sefa Koyo			
Sefa Fingo	FV	Sefa Fingo			
Sefa Fingo (red)	FV	Sefa Fingo			
Sefa Nunfingo	FV	Sefa Nunfingo			
Sefa Nunfingo (white)	FV	Sefa Nunfingo			
Bendou	FV	Bendou Bendung			
Hombo Wulengo	FV	Hombo Wulengo			
Mani Mesengo	FV	Mani Mesengo Mani Tereyengo			
Sainy Kolly	US	Sainy Kolly			
Sonna Mano	US	Sonna Mano			
total # sampled varieties[2)] based on morphological data	38	18	8	10	16
total # sampled varieties based on variety names	49	20	11	10	16
total # of farmers	56	24	9	12	11
total # samples	100	49	13	17	21

*) MV = Formal Variety; FV = Farmer Variety; US = Unclear Status
1) Identified as MV, but unclear which MV

Millet

For millet, the nomenclature in the different villages suggested that within each village several varieties are grown and that there is an overlap in variety use between all villages (Table 10.5). However, in each village all farmers, or a large majority of the farmers in the case of Faraba, grow the same millet variety. Furthermore, it appeared that only in the villages of Janack and Kitti the same white millet variety is grown, and that in the villages of Tujereng and Faraba two different black varieties are grown. In total, 10 variety names were given by farmers, whereas only three varieties could be recognised, based on the morphological and molecular data.

Table 10.5: Farmer names of the millet varieties sampled in Tujereng, Kitti, Faraba and Janack. Variety names printed in bold are the ones most often mentioned by farmers.

variety	Tujereng	Kitti	Faraba	Janack
Black sanyo (from Tujereng)	**sanyo** sanyofingo sanyotima nyokoyndingo			
Black sanyo (from Faraba)			**sanyo** majo komba	
White sanyo		**sanyo** majokoyo	sanyo	**sanyo** serengo boltep

Comparison between villages

Rice

A PCA analysis was performed to investigate the level of morphological diversity between the investigated villages. In this analysis no distinction was made between formal and farmer varieties. PCA analysis showed that the vegetative characteristics mostly contributed to the first component and that the reproductive traits mostly contributed to the 2nd component. Graphical representation of the data shows a large similarity in rice morphology between villages, as no clear clustering was observed of varieties according to village (Figure 10.2). That the villages of Tujereng and Janack hardly share varieties (Table 10.4) does not show very clearly in Figure 10.2. In Figure 10.2 a line has been added to separate the *indica* and *japonica* subspecies, based on the results of the molecular analysis (discussed below). Samples from all four villages were observed in the *indica* group, whereas in the *japonica* group, only samples from Tujereng and Janack were found. It appeared that almost all old farmer varieties from Tujereng belonged to the *japonica* group, while most of the new farmer varieties from Tujereng fell within the *indica* group. Farmers indicated that the new farmer varieties entered Tujereng from 1970 onwards, while the old varieties had been in the village before 1950, at least. The *O. glaberrima* samples appeared more similar to the *japonica* group than to the *indica* group.

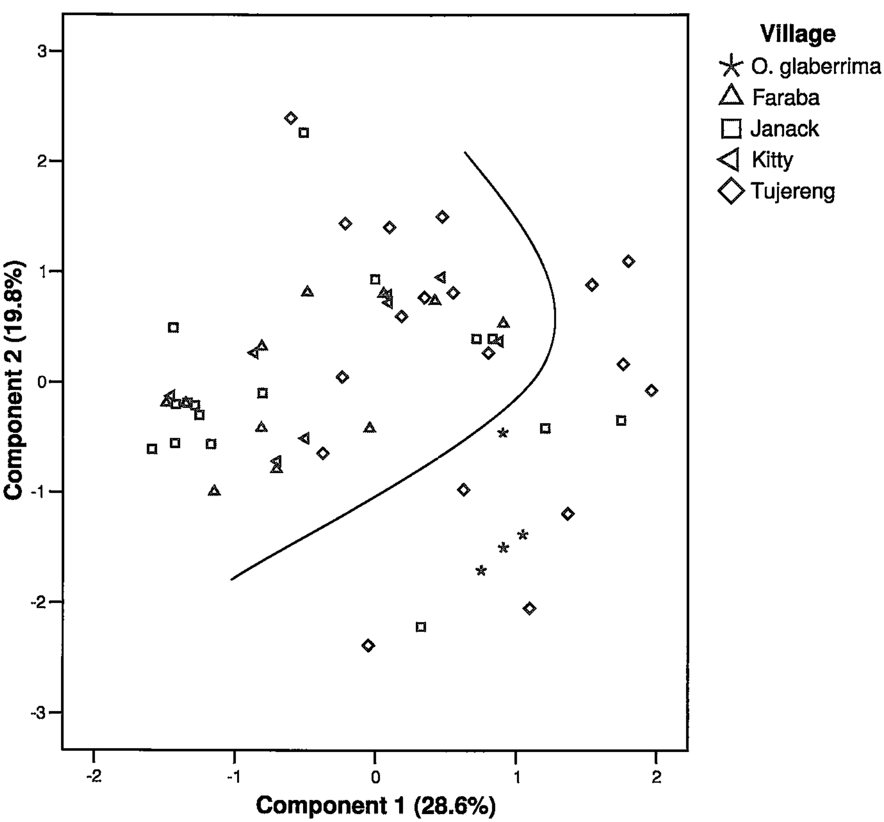


Figure 10.2: Relationship between upland rice varieties collected from 4 villages in The Gambia based on PCA analysis of the morphological data. The line separating the varieties is based on the results of the AFLP analysis, and distinguishes the material belonging to the *indica* (left side) and *japonica* (right side) subspecies.

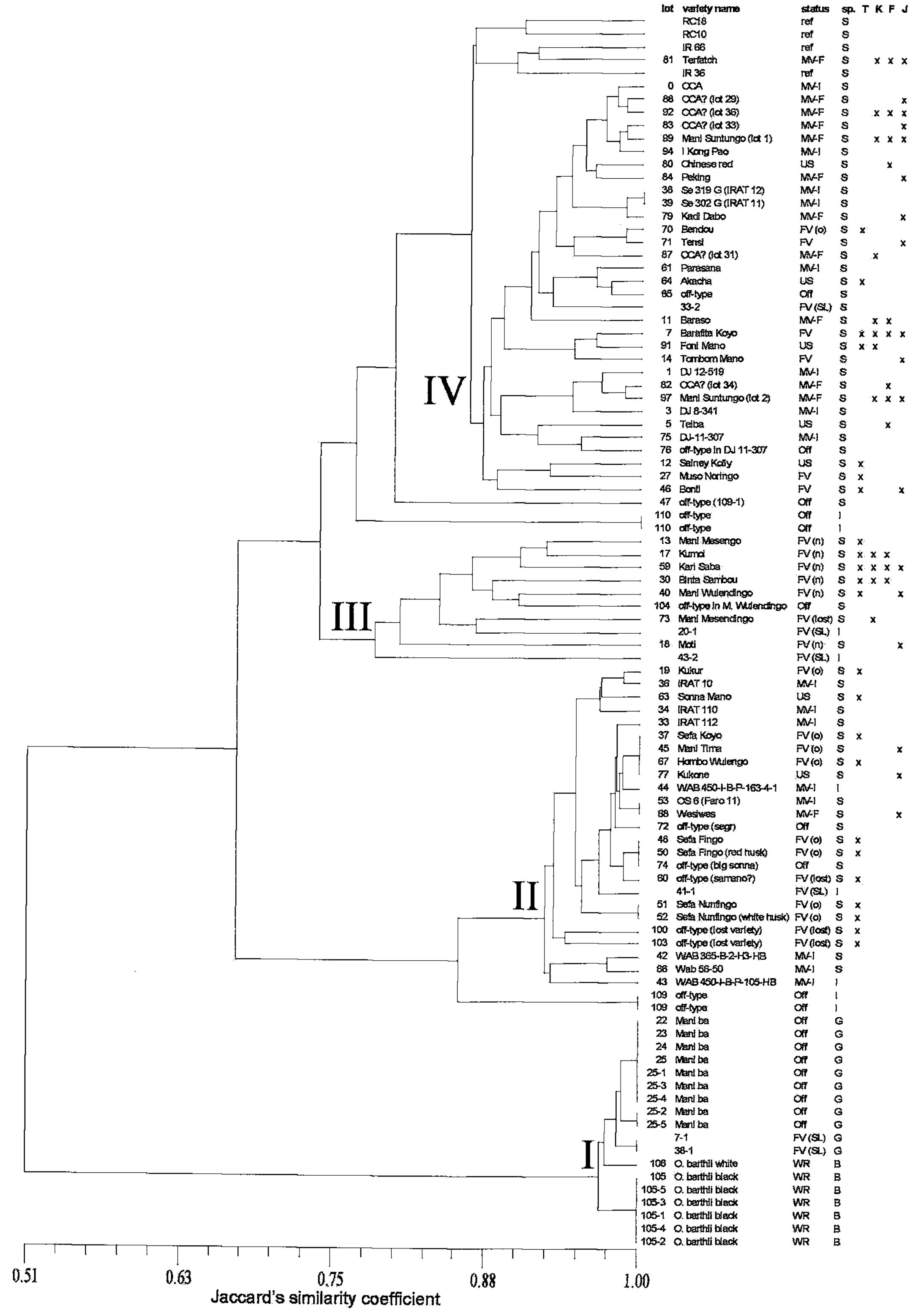

lot variety name status sp. T K F J
RC18 ref S
RC10 ref S
IR 66 ref S
81 Terfatch MV-F S x x x
IR 36 ref S
0 OCA MV-I S
88 OCA? (lot 29) MV-F S x
92 OCA? (lot 36) MV-F S x x x
83 OCA? (lot 33) MV-F S x
89 Mani Suntungo (lot 1) MV-F S x x x
94 I Kong Pao MV-I S
80 Chinese red US S x
84 Peking MV-F S x
38 Se 319 G (IRAT 12) MV-I S
39 Se 302 G (IRAT 11) MV-I S
79 Kadi Dabo MV-F S x
70 Bendou FV (o) S x
71 Tensi FV S x
87 OCA? (lot 31) MV-F S x
61 Parasana MV-I S
64 Akacha US S x
65 off-type Off S
33-2 FV (SL) S
11 Baraso MV-F S x x
7 Barafita Koyo FV S x x x x
91 Foni Mano US S x x
14 Tombom Mano FV S x
1 DJ 12-519 MV-I S
82 OCA? (lot 34) MV-F S x
97 Mani Suntungo (lot 2) MV-F S x x x
3 DJ 8-341 MV-I S
5 Teiba US S x
75 DJ-11-307 MV-I S
76 off-type in DJ 11-307 Off S
12 Sainey Kolly US S x
27 Muso Noringo FV S x
46 Bonti FV S x x
47 off-type (109-1) Off S
110 off-type Off I
110 off-type Off I
13 Mani Mesengo FV (n) S x
17 Kumoi FV (n) S x x x
59 Kari Saba FV (n) S x x x x
30 Binta Sambou FV (n) S x x x
40 Mani Wulendingo FV (n) S x x
104 off-type in M. Wulendingo Off S
73 Mani Mesendingo FV (lost) S x
20-1 FV (SL) I
18 Moti FV (n) S x
43-2 FV (SL) I
19 Kukur FV (o) S x
36 IRAT 10 MV-I S
63 Sonna Mano US S x
34 IRAT 110 MV-I S
33 IRAT 112 MV-I S
37 Sefa Koyo FV (o) S x
45 Mani Tima FV (o) S x
67 Hombo Wulengo FV (o) S x
77 Kukone US S x
44 WAB 450-I-B-P-163-4-1 MV-I I
53 OS 6 (Faro 11) MV-I S
68 Wesiwes MV-F S x
72 off-type (segr) Off S
48 Sefa Fingo FV (o) S x
50 Sefa Fingo (red husk) FV (o) S x
74 off-type (big sonna) Off S
60 off-type (samano?) FV (lost) S x
41-1 FV (SL) I
51 Sefa Nunfingo FV (o) S x
52 Sefa Nunfingo (white husk) FV (o) S x
100 off-type (lost variety) FV (lost) S x
103 off-type (lost variety) FV (lost) S x
42 WAB 365-B-2-H3-HB MV-I S
66 Wab 56-50 MV-I S
43 WAB 450-I-B-P-105-HB MV-I I
109 off-type Off I
109 off-type Off I
22 Mani ba Off G
23 Mani ba Off G
24 Mani ba Off G
25 Mani ba Off G
25-1 Mani ba Off G
25-3 Mani ba Off G
25-4 Mani ba Off G
25-2 Mani ba Off G
25-5 Mani ba Off G
7-1 FV (SL) G
38-1 FV (SL) G
106 O. barthii white WR B
105 O. barthii black WR B
105-5 O. barthii black WR B
105-3 O. barthii black WR B
105-1 O. barthii black WR B
105-4 O. barthii black WR B
105-2 O. barthii black WR B
IV
III
II
I
0.51
0.63
0.75
0.88
1.00
Jaccard's similarity coefficient

Figure 10.3 (page 189): UPGMA cluster analysis of upland rice varieties based on the AFLP data. MV-I = Formal variety from institute, MV-F = Formal variety from farmer, FV = Farmer variety (o = old, n = new), US = Unclear status, Off = Off-type, WR = Wild rice; S = O. sativa, G = O. glaberrima, I = genotype derived from interspecific hybridisation, B = O. barthii, SL = Sierra Leone, ref = reference variety, T =Tujereng, K = Kitti, F = Faraba and J = Janack.

Four main clusters could be observed, based on the assessment of genetic relationships using AFLP analysis (Figure 10.3). All *O. glaberrima* and *O. barthii* samples grouped together in cluster I, whereas clusters II-IV contained the *O. sativa* samples. All Wab varieties observed in cluster II are known to belong to the *japonica* subspecies (Ghesquière *et al.*, 1997), suggesting that cluster II represents a *japonica* group. Similarly, IRRI varieties are known to belong to the *indica* subspecies (Dalrymple, 1986), suggesting that cluster IV represents an *indica* group. Because cluster III showed the closest relationship with cluster IV, cluster III was also considered an *indica* group. Materials cultivated in all 4 villages were found in clusters III and IV, whereas cluster II was dominated by samples from Tujereng and a few from Janack, but lacked samples from Kitti and Faraba. Cluster II also contained all old farmer varieties except one, whereas cluster III consisted only of 'new' farmer varieties and two interspecific derivatives from Sierra Leone as identified by Jusu (1999). These results were in good agreement with those from the morphological analysis. Despite the general good accordance between the data types, some discrepancies were observed. For example, the *O. sativa* farmer varieties *Sefa Koyo*, *Hombo Wulengo*, *Mani Tima* and *Kukone*, which were morphologically very distinct from each other, showed no differences at the molecular level. In contrast, the varieties *Moti* and *Kumoi*, which were morphologically very similar, showed a wide genetic distance at the molecular level.

The Shannon information index was used to calculate the level of molecular diversity at village level (Table 10.6). Diversity values were highest for Tujereng and Janack, because in those villages both indica and japonica varieties are cultivated, while in the villages Kitti and Faraba only indica varieties are cultivated. The substantially smaller level of genetic diversity within the japonica group, compared to the indica group, was in contrast to that observed from the morphological data (Figure 10.2).

Table 10.6: Level of diversity for upland rice in the 4 investigated villages based on molecular data, calculated with the Shannon information index.

Shannon information index	Tujereng	#	Kitti	#	Faraba	#	Janack	#
all varieties	0.32[1)]	19	0.21	12	0.21	12	0.28[1)]	18
indica cluster (III & IV)	0.24	11	0.21	12	0.21	12	0.21	15
japonica (cluster II)	0.04	8	-	-	-	-	0.01	3
Farmer Varieties	0.32	17	0.19	4	0.19	4	0.30	8
Formal Varieties	-	-	0.11	6	0.11	6	0.17	9

[1)] After 30 at random drawings of 12 samples for Tujereng and Janack, the average values are 0.31 and 0.27 for respectively Tujereng and Janack.

Millet

Morphological data showed that all millet samples belonging to the late millet varieties *black sanyo*, *white sanyo* and *majo* grouped together in one cluster (Figure 10.4). The *black sanyo* from Faraba clustered closely with the *white sanyo*, and the only differences observed between the two varieties were seed colour, 1000-seed weight and bristle colour (Table 10.7). The *black sanyo* from Tujereng differed significantly from the *black sanyo* from Faraba for 7 traits and from the *white sanyo* for 4 traits. The clearest difference observed between *sanyo* (both black and white) and *majo* was that *majo* has very short bristles, whereas *sanyo* has long bristles. According to farmers, two varieties of *majo* exist, one with long spikes and one with short spikes. However, the clustering of the *majo* in Figure 10.4 is not in accordance with farmers' descriptions of spike size, suggesting that farmers' variety descriptions based on qualitative traits (such as seed colour or presence of bristles) are more suitable to differentiate varieties than quantitative traits such as spike length. Farmers also indicated that two varieties of *white sanyo* exist, one with long and one with short spikes, but in this study no clear differences in spike length between the *white sanyo* samples were found.

Using only *sanyo* and *majo* samples, the molecular data indicated a higher level of similarity for the millet varieties than observed from the morphological data (Figure 10.5). In particular, the two *black sanyo* varieties from Faraba and Tujereng appeared more closely related, based on the AFLP data than appeared from the morphological data. In contrast to the morphological data, the molecular data separated *majo* from the investigated *sanyo* varieties

The level of genetic diversity using the Shannon information index was 0.26 for all samples combined, ranging from 0.21 for the *majo* sample to 0.26 for one of the Faraba samples (Figure 10.5). The samples from Faraba and Kitti showed the highest levels of genetic diversity.

MV/FV	origin	variety
FV	Kitti	white sanyo
FV	Kitti	white sanyo
FV	Janack	white sanyo
FV	Sangajor	white sanyo
MV	ISRA	white sanyo
FV	Kitti	white sanyo
FV	Sangajor	white sanyo
FV	Janack	white sanyo
FV	Janack	white sanyo
FV	Faraba	black sanyo
FV	Faraba	black sanyo
FV	Faraba	black sanyo
FV	Damphakunda	majo
FV	Damphakunda	majo
FV	Sanending	majo
FV	Sanending	majo
FV	Tujereng	black sanyo
FV	Tujereng	black sanyo
MV	ICRISAT	Leonis
MV	ICRISAT	Dauro

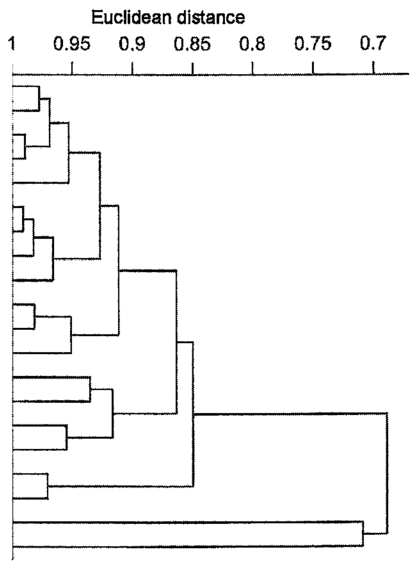
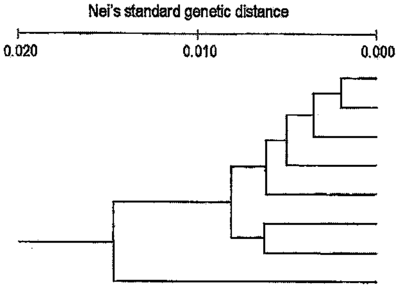


Figure 10.4: Relatedness between millet varieties based on morphological characterisation; MV = formal varieties; FV = farmer varieties.



variety	village	Shannon index	# poly-morphisms
white sanyo	Kitti	0.26	53
white sanyo	Janack	0.24	49
white sanyo	Janack	0.24	51
black sanyo	Faraba	0.26	58
black sanyo	Faraba	0.24	46
black sanyo	Tujereng	0.23	52
black sanyo	Tujereng	0.22	47
majo	Sanending	0.21	47

Figure 10.5: Relatedness between millet varieties based on AFLP analysis. Variety names are followed by the name of the village in which the material was collected and the level of diversity calculated with the Shannon information index and the # polymorphisms per seed lot.

Table 10.7: Differences between varieties for various quantitative characteristics based on ANOVA and Duncan multi-comparison tests. Varieties that have the same letter for a particular trait are not significantly different for that trait at a significance level of p= 0.05.

variety	days to 50% flowering	# tillers	plant height	stem diameter	separation	leaf length	leaf width	spike length	spike width
Majo [1)]	88.3 b	8.3 bcd	303 bcd	13.5 b	22.0	74.0 b	5.2 bc	39.8 c	22.3 b
Black sanyo, Faraba	92.8 d	10.3 d	328 d	13.7 b	21.9	75.0 b	4.9 b	40.4 c	23.3 b
Black sanyo, Tujereng	90.3 bc	7.4 bc	300 bc	14.8 c	21.0	73.0 b	5.5 c	36.7 ab	27.0 c
White sanyo [1)]	91.2 cd	10.4 d	323 cd	13.5 b	21.8	75.0 b	5.0 b	38.0 bc	22.1 b
Sanyo, ISRA	96.5 e	9.4 cd	361 e	13.4 b	23.2	77.4 b	4.9 b	40.7 c	22.1 b
Leonis, ICRISAT	99.5 f	6.2 ab	287 b	12.6 b	21.8	65.9 a	5.0 b	39.6 bc	19.2 a
Dauro, ICRISAT	82.3 a	4.5 a	228 a	11.6 a	21.5	68.4 a	4.2 a	35.0 a	17.1 a
p (based on ANOVA)	0.000	0.000	0.000	0.003	0.232	0.049	0.000	0.011	0.000

[1)] collected from several villages

Comparison between farmer and formal varieties

Rice

In order to investigate the level of morphological similarity between farmer and formal varieties a PCA analysis was performed on a subset of the samples. Traits that contributed most to component 1 were predominantly vegetative traits, while traits that contributed most to component 2 were predominantly inflorescence related traits. Subsequently, differences between varieties were graphically represented by a scatter plot of the first two components of the PCA analysis, showing a very restricted degree of overlap between formal and farmer varieties (Figure 10.6). The formal varieties were mainly clustered into two groups. Group A contains the majority of varieties that were collected from and cultivated by farmers and are referred to as 'MV collected from farmers'. Group B, referred to as 'MV recommended for cultivation', contains almost only varieties that were recommended for rice farming in The Gambia. The formal varieties in cluster A had various origins and most of them were very short, had medium sized grains and were relatively easy to thresh. Cluster B consists of IRAT and WARDA varieties, which were of medium height, with glabrous husks and big seeds that were not easy to thresh. In Figure 10.3 all DJ ___ varieties can be found in one sub-cluster. The IRRI-varieties can be found in a sub-cluster separate from the materials collected from farmers. The farmer varieties can also be divided into two groups: those that farmers cultivate nowadays, in Figure 10.6 indicated as 'farmer variety', and those not cultivated anymore but still found as off-types in the field, indicated as 'farmer variety not cultivated anymore'. This establishes that there is substantial change in genetic make-up of farmer varieties over the past 50 years.

Separation between farmer and formal varieties was partly also observed from the molecular data, as cluster III only consisted of farmer varieties (Figure 10.3). However, clusters II and IV showed an irregular grouping of formal and farmer varieties. In contrast to the morphological data, *O. glaberrima* samples showed a clear distinction from the *O. sativa* samples based on the AFLP data. Of the 92 polymorphic bands, 29 bands were species-specific. Two plants, forming the progeny of an interspecific hybrid that was found in the trial field, predominantly showed typical *O. sativa* bands, but also showed 7 and 8 typical *O. glaberrima* bands. Both plants clustered with *O. sativa*, one in cluster II and the other in between cluster III and IV. Two Nericas, derived from interspecific crosses between *O. sativa* and *O. glaberrima* followed by two backcrosses to *O. sativa* and pollen culture, were found in cluster II. One Nerica (WAB 450-I-B-P-105-HB) showed two bands typical for *O. glaberrima*, while the other Nerica (WAB 450-I-B-P-163-4-1) did not show any bands typical for *O. glaberrima*, suggesting that an accession with *O. glaberrima* parentage does not necessarily show this in the molecular analysis. An off-type (lot 47) found in a sample collected from a farmer, was located in between cluster III and IV and showed one band typical for *O. glaberrima*. Three accessions (lot 40, 73 and 104) in cluster III each showed a different band typical for *O. glaberrima*. Furthermore, cluster III showed variation for 3 bands which were either present in all *O. sativa* accessions in clusters II and IV and absent in all *O. glaberrima* accessions in cluster I or vice versa. These findings indicate that some farmer varieties and off-types resulted from interspecific hybridisation. However, a formal variety (lot 81), probably developed at IRRI, shared with lot 73 the band typical for *O. glaberrima*, which means that some bands are not typical for *O. glaberrima*, but just very rare.

Based on the Shannon index, a higher level of genetic diversity was observed within the group of farmer varieties than in the group of formal varieties (Table 10.8). Of the various subgroups, the farmer varieties of the *japonica* subspecies represented the least genetic diversity, while the farmer varieties in cluster III represented the most genetic diversity.

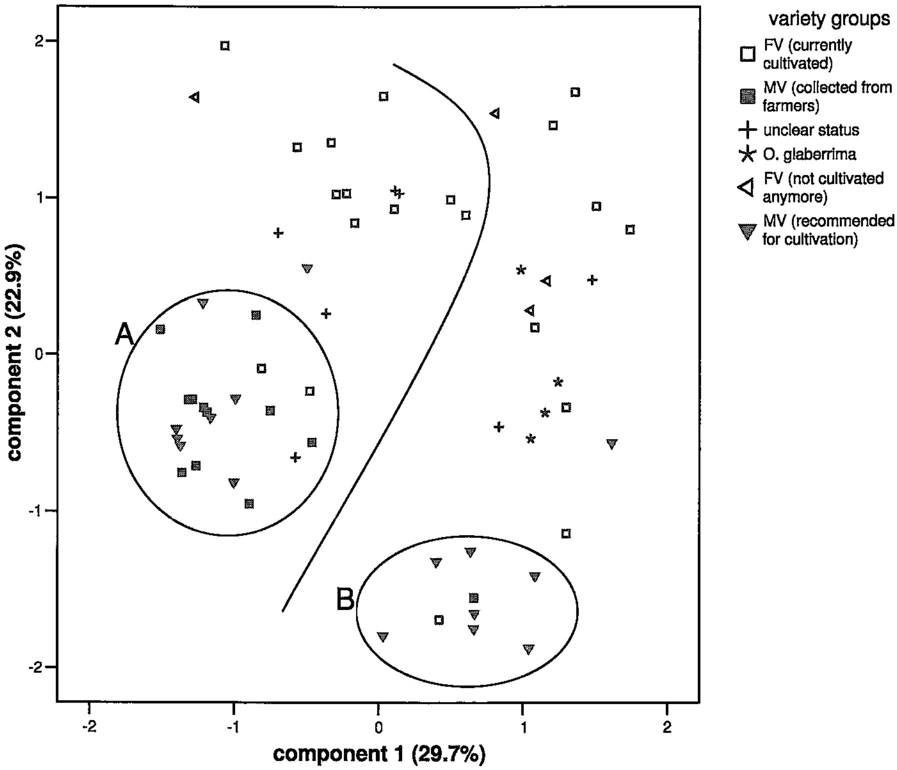


Figure 10.6: Relationship between formal varieties and farmer upland rice varieties of The Gambia based on PCA analysis of the morphological data. Encircled groups of varieties indicate two clusters of formal varieties. The line separating the varieties is based on the results of the AFLP analysis, and distinguishes the material belonging to the *indica* (left side) and *japonica* (right side) subspecies.

Table 10.8: Level of genetic diversity for various variety groups belonging to the *O. sativa indica* and *japonica* subspecies based on molecular data, calculated with the Shannon information index and counting of # polymorphisms.

cluster	variety group [1]	# samples	shannon information index	# polymorphisms
all	MV and FV combined	48	0.31	63
all	MV (all)	28	0.26	51
	MV (collected from farmers)	12	0.17	43
	FV	20	0.32	56
indica, cluster IV	MV (all)	19	0.12	29
	MV (collected from farmers)	11	0.11	26
	FV	6	0.11	18
indica, cluster III	FV	6	0.15	28
japonica, cluster II	MV (all)	9	0.06	12
	FV	8	0.03	7

[1] MV = formal varieties; FV = farmer varieties

Millet

The two formal millet varieties from ICRISAT were clearly different from the farmer varieties. It should be noted that the two formal varieties were not well adapted to Gambian conditions. The formal (white) *sanyo* from ISRA, developed via mass selection, clustered closely with the *white sanyo* samples collected from farmers, indicating a close genetic relationship between the formal *sanyo* with the *white sanyo* collected from farmers.

10.4 Discussion

Homonyms and synonyms

To study crop diversity based on variety names is difficult because of the existence of many homonyms and synonyms. One aspect is that names can lead to both over and underestimation of the number of varieties used by farmers (see Chapter 6). For millet, the number of names was three times as many as the number of varieties found, based on morphological analysis. Another aspect is that one might over or underestimate the varieties villages share because of the homonyms and synonyms. In a study on Enset (*Ensete ventricosum* [Welw.] Cheesman) in southwest Ethiopia, it was found that 25% of the collected clones were duplicates, which was related to different use purposes and the changing of names upon exchange between communities (Negash *et al.*, 2002). In a case study on sorghum in Ethiopia, involving four villages all situated along the main highway between Addis Ababa and Woldeya, it was found that the naming of sorghum varieties was consistent between the villages (Teshome *et al.*, 1997; Tunstall *et al.*, 2001). Of the 48 collected varieties, 35 were grown in at least three of the four villages (Tunstall *et al.*, 2001). This number is much higher than the 7 of 38 rice varieties grown in at least three villages in this study. Hence, the risk of over and underestimating the level of varieties shared among villages differs between areas and crops.

Genetic diversity between villages

Based on the different names given to the various upland rice varieties, one would expect clear differences in genetic diversity between the villages. Morphological and molecular analyses, however, indicated fewer differences in genetic diversity between villages than expected. The villages of Tujereng and Janack showed greater diversity in rice due to the presence of *japonica* varieties. Traditionally, in both Asian and African rice cultivation most *japonica* varieties are upland varieties while most *indica* varieties are lowland varieties (Glaszmann, 1987; de Kochko, 1987b). In the past, this also seemed to apply to The Gambia. Nowadays, however, many of the varieties commonly cultivated in the uplands belong to the *indica* subspecies. A reason that *japonica* varieties were only found in the villages of Tujereng and Janack is that they have typical uplands, whereas Kitti and Faraba do not. It should also be noted that it seems likely many of the 'old' *japonica* varieties from Tujereng will be lost in the near future, because these old varieties are not suited to current climatic conditions. Farmers from Tujereng said they had tried most of the formal varieties included in this study, but that for various reasons (too short, too early) they did not adopt them. In 2003, a few farmers in Tujereng started experimenting again with these varieties, partly a result of poor rainfall in 2002.

As for rice, farmers give many different names to their millet varieties, which suggests that within each village several millet varieties are grown, whereas often only one variety, or in a few cases two varieties, is grown in each village. In a case study on millet in Niger it was also concluded that the differences between varieties do not relate linearly to the names given to these varieties (Busso *et al.*, 2000). Even though morphological analysis indicated that the millet from Tujereng is different from the millet grown in the other three villages, molecular analysis showed that all millet varieties collected from the various villages share the same genetic background. This suggests that selection pressures (both natural and human) do not vary between the villages in the western part of the country, except for seed colour and perhaps seed size. For millet, variety choice seems to be the result of social and cultural factors rather than agro-ecological factors. In Tujereng and Faraba people prefer black millet, whereas in Janack and Kitti people prefer white millet because of differences in taste. Traditionally, Mandinka people grow black millet and Jola people grow white millet. Interestingly, for rice, no preference was found for red or white seed colour. In Sierra Leone it was found that the Mende prefer red seeded rice types (Richards, 1996b). In another case study on rice, on the island of Bohol in the Philippines, it was found that rice farmers strongly favour rice varieties with a red pericarp (Bertuso *et al.*, 2005). This underscores the complexity of cultural factors shaping farmer variety selection criteria.

One of the main questions in this study was whether local crop gene pools become genetically more uniform over time or not. The results on new and old farmer rice varieties from Tujereng show that the new varieties are morphologically less diverse than the old varieties, whereas they are much more diverse than the old varieties at the molecular level. This suggests that the two hypothesised processes outlined in the introduction – genetic diversity being maintained over time in local gene pools and genetic diversity decreasing over time - may alternate. That the old varieties are morphologically very distinct, but very similar at the molecular level is in accordance with the idea that if no new material enters a community and selection takes place within the existing gene pool, phenotypic diversity increases but genetic diversity may actually decrease (Cox and Wood, 1999). Some women in Tujereng indicated that some of the old rice varieties were all found in one other old rice variety (all of which were among the samples).

An important process that leads to genetic diversification is introduction of new seed types. All new farmer rice varieties in Tujereng arrived just before or after the Sahelian drought (early 1970s), when rainfall was insufficient for the cultivation of the older varieties. When women visit relatives, often over long distances, they often bring new rice varieties back to their village. Because the distances they travel are sometimes 200 km or more (often to Senegal and occasionally even to Guinea Bissau), rice seed sources are geographically very dispersed. In this way rice genetic diversity is (unconsciously) increased within a village. That farmers unconsciously maintain genetic diversity by obtaining varieties from distant places is also suggested by Cox and Wood (1999). Furthermore, long distance exchange of varieties increases the chances of the development of genetically distinct, new varieties in the field through cross-pollination. The construction of roads in the rural areas of The Gambia only started after World War II (Haswell, 1963). It is difficult to indicate when exactly this resulted in improved transport facilities, but it seems likely that, from the 1960 onwards, improved infrastructure helped women to travel more frequently and over larger distances, resulting in more frequent exchange of rice genetic diversity.

This would mean that after 1970 a period of rice genetic diversification started and possibly still continues, while the period prior to 1970 might be considered an era of genetic homogenisation. The implication is that rice genetic homogenisation happens during periods with relatively stable agro-ecological conditions, while genetic diversification is a likely product of periods of changing agro-ecological conditions, During periods of stability it is less necessary for farmers to search for rice varieties, while in periods of change farmers need to travel and look for better adapted varieties.

There is also another factor affecting rice genetic diversity in this case study. It is likely that the cultivation of *japonica* and *indica* varieties in the same field, or in adjacent fields, promoted the emergence of new genetic diversity through inter-subspecific crosses. This might also have contributed to the fact that new rice farmer varieties represent more genetic diversity than the old rice farmer varieties.

For millet, most farmers reported they hardly see any new genotypes in their fields. Because of the large genetic variation and continuous cross-pollination within millet varieties, chances that completely new genotypes will emerge and remain stable are very small. Hence, it is likely that any new phenotype will go unnoticed in the field and will be 'submerged' in the wide phenotypic diversity in the field. For millet, the only chance for noticeable variation to appear would be when genetically distinct varieties are grown side by side. The results of this study indicated, however, that all late millet varieties grown in The Gambia are genetically similar. This means that farmer exchange of different millet varieties over long distances would unlikely have a clear, positive effect on genetic diversity. So whereas for rice, an inbreeding crop, bringing in varieties from distant places might be crucial to the maintenance of genetic diversity in a gene pool, this does not seem to be necessary for millet, an out-breeding crop. It is likely that the higher the rate cross-pollination in a crop, the less liable is genetic diversity to fluctuate at gene pool or crop level. Through variety choices farmers have little influence on crop genetic diversity in millet, while they can have such an impact on rice. Whereas for millet, the majority of crop genetic diversity can be found within varieties, for rice, most crop genetic diversity is found between varieties. This difference is very much related to the different breeding systems of the two crops and it seems the inverse relation between the rate of cross-pollination and the fluctuation of genetic diversity in gene pools will be true for other in- and out-breeding crops. A study on maize (an outbreeder) in Mexico indicated little differentiation between populations (Pressoir and Berthaud, 2004), while studies on wheat (an inbreeder) in Jordan and barley (also an inbreeder) in Syria and Jordan indicated wide differentiation between landraces (Jaradat, 1991; Weltzien, 1989).

Farmer and formal varieties

The other main question was whether the introduction of formal varieties increases or reduces genetic diversity in farming systems. The results on rice indicated that the formal varieties represent less genetic diversity than the farmer varieties, a finding in agreement with Chang (2003). However, because formal varieties represent different genetic diversity than farmer varieties and farmers only partially replace farmer varieties with formal varieties, total genetic diversity increases, which is in line with other studies on rice and millet (Dennis, 1988, Vom Brocke *et al.*, 2002). It should also be noted, however, that it is likely that the genetic diversity represented by farmer varieties changes over time, and that if this study had been conducted 40 years ago (before the Sahelian drought), the difference in genetic diversity between formal and farmer rice varieties might have been less marked.

It is worth noting, further, that the large genetic diversity represented by the new farmer varieties in cluster III in Figure 10.4 is the result of inter-subspecific or interspecific crosses. These varieties cluster together with some of the materials that were identified by Jusu (1999) as derivatives of interspecific hybrids based on morphological analysis. Further, molecular analysis showed that two plants formed the progeny of an interspecific cross between *O. sativa* and *O. glaberrima*. An iso-enzyme study on West African rice also revealed intermediate genotypes, which were attributed to inter-subspecific or inter-specific crosses (de Kochko 1987a). However, the future chances of interspecific hybridisation in Gambian rice fields will reduce and, hence, the chances of the development of genetic unique materials may decrease. Reasons that, nowadays, the younger generation does not grow *O. glaberrima* are that it is not drought tolerant and difficult to pound.

Although no formal late millet varieties are grown in The Gambia, and those from ICRISAT are not adapted to Gambian conditions, the morphological data suggest that genetic diversity will increase significantly, if suitable, genetically different, formal late millet varieties are introduced. In Rajasthan, India, it was shown that introgression of formal millet varieties into farmer millet varieties can also lead to a higher level of diversity within varieties (Vom Brocke *et al.*, 2002). This strategy to improve farmer varieties applies more to cross-pollinating crops than to self-pollinating crops. In a study on rice on the island of Bohol in the Philippines it was found that farmers developed new rice varieties on the basis of formal varieties (Bertuso *et al.*, 2005).

When the various formal rice varieties are compared with each other, both morphological and molecular data indicated that varieties developed at the same institute resemble each other, but that there are large differences between varieties developed at different institutes. This suggests that the best way to ensure genetic diversity in formal rice varieties is to test and distribute varieties from breeding programs from different institutes. This also shows a parallel to farmers maintaining genetic diversity by bringing varieties from different places. At the moment, however, most, if not all, formal material tested and distributed to farmers in The Gambia comes from one institute, WARDA. If this continues in the future, it might have a negative impact on genetic diversity in farmers' fields. Because the new farmer rice varieties show large genetic distances, these varieties might carry potentially valuable traits useful for formal rice breeding. Most of the polymorphisms present in farmer rice varieties but not in formal rice varieties were found in this group of new farmer rice varieties. This then would also mean that it would be beneficial for breeders to visit farmers every 10 years or so to collect rice germplasm from farmer varieties. This applies less to cross-pollinating crops like millet. Since diversity represented by farmer varieties is generally under-exploited in breeding programs (Hawtin *et al.*, 1997), a change in breeding practices will be required to ensure the utilisation of this diversity. Such genetic resources might particularly be useful in breeding programs aimed at marginal low-input farming systems.

10.5 Conclusions

The following conclusions can be drawn:

- Assessment of numbers of rice and millet varieties based on variety naming leads to both over and underestimations of the actual numbers of varieties used by farmers..
- Although villages have different sets of rice varieties and millet varieties, differences in morphological diversity between villages are small. However, molecular diversity at village level clearly varies for rice but not for millet.
- The differences in rice genetic diversity between villages are primarily caused by the fact that in two villages only rice varieties belonging to the *indica* subspecies are grown, while in the other two villages, varieties belonging to both the *indica* and *japonica* subspecies are grown.
- Farmer and formal rice varieties form two separate groups morphologically, but are less clearly differentiated at the molecular level.
- Farmer rice varieties show more genetic diversity than the formal varieties, but formal varieties do contribute to crop genetic diversity at village level.
- Old farmer rice varieties look very distinctive morphologically but are similar to each other at the molecular level, while new farmer rice varieties which look similar morphologically are very different at the molecular level.
- The new farmer rice varieties most likely result from interspecific gene flow as they show several molecular markers typical of *O. glaberrima*, form a distinct cluster at the molecular level and show large genetic distances between members within the cluster.

- The tested progeny of an interspecific hybrid is evidence of interspecific gene flow at field level.
- The genetic distances between millet varieties are relatively small, suggesting a common origin.
- Genetic diversity within millet populations is almost as large as the total genetic diversity found in all tested populations.
- It is suggested that periods of genetic homogenisation and genetic diversification for rice may alternate. The Sahel drought of the 1970s marks the boundary between old (and homogenous) and new (and diverse) farmer varieties. This suggests genetic homogenisation is correlated with stable periods, while genetic diversification is related to periods of environmental change.
- At village level, rice genetic diversity seems more prone to fluctuation than millet genetic diversity.
- Women introducing a new rice variety to a village have a bigger impact on crop diversity than men bringing a new variety of millet to a village. This is probably the result of the different breeding systems of the two crops.
- The best strategy to increase genetic diversity represented by formal varieties in farmers' fields is to distribute formal varieties obtained from different institutes. (i.e. institutional diversity is good for biodiversity).
- The rice genetic diversity that develops in farmers' fields may carry potentially valuable traits useful for formal breeding.

11 Local adaptation

11.1 Introduction

One of the main research questions in this thesis is the importance of gene flow for maintaining adaptability and resilience of low-input farming systems. Adaptation is a concept that can be used at different levels; the levels that are focused on in this thesis are the variety level and the farming system level. Chapter 2 described how Gambian farmers adapted to changing ecological, economic and social conditions. They grow a range of crops and are often involved in a range of other activities. As conditions change, farmers change the ratio of crops planted and other activities, but often maintain diversity as insurance. During the rainy season women organise insurance by growing several rice varieties, whereas men organise insurance by growing several crops. This suggests that adaptation and risk can be managed in different ways.

Chapters 5 and 6 provided information about managing adaptation at farming system level, whereas Chapters 4 and 7 provided information about managing adaptation at field level. Although these two levels are related to each other, adaptation also involves different factors at field level and at farming system level. Chapter 4 suggested that specific adaptation at micro-level can only occur under specific stable conditions, which often do not apply to marginal low-input systems. Chapters 3 and 4 indicated that, even though there are some slight ecological differences between the four focus villages for millet cultivation, conditions vary greatly between years, blurring these ecological differences. From Chapter 3 it became clear that the rice ecologies are more complex than the millet ecologies but also that ecological differences between the uplands and the upper stretches of the transitional zone are relatively small. Despite these relatively small differences, Chapter 10 showed that different varieties are grown in different villages for both rice and millet.

So, a remaining question is whether adaptation at field level could actually play a role in variety choice in the four focus villages. To answer that question for millet, an experiment was set up in which four millet seed lots from the four focus villages were compared in 4 farmer-managed trials in each of these four villages. When setting up these trials, it was not known that the genetic differences between the varieties were very small (as shown by later analysis - Chapter 10). For rice, it was tried to set up trials using the same experimental arrangements for millet, but it was not possible to get rice seed of the same variety in all four villages in 2002. In this chapter the results of an experiment on millet focusing on adaptation at field level are described and discussed. In the discussion these data will also be related to farmer seed selection and farmer variety choice. First, some concepts on adaptation and plasticity are reviewed.

Wide and local adaptation

In literature it is often mentioned that in marginal environments farmers choose farmer varieties rather than formal varieties because the farmer varieties are better adapted to the local field conditions and consequently yield better (Hawtin et al., 1997; Weltzien and Fischbeck, 1990; Mushita, 1993). Because formal varieties are developed under high-input conditions, formal varieties are not the best performers under low-input conditions (Ceccarelli 1997). Likewise, because farmer varieties are adapted to low-input conditions, they do not respond well to high-input levels. Furthermore, it is often stated that formal varieties are more widely adapted than farmer varieties which are often locally adapted (Hawtin et al., 1997). However, because formal varieties are often grown under favourable conditions, they can grow in geographically diverse areas which are rather similar ecologically (Ceccarelli, 1989; 1994). Ceccarelli (1989) argues that wide adaptation exists only within a certain range of environments. Ceccarelli (1989) asked the question how wide is wide adaptation. The other question that needs to be asked is how local is local adaptation. It is sometimes suggested that farmer management results in specific adaptation at micro-level (Cleveland et al., 1994; Berg et al., 1991; Busso et al., 2000).

Definitions of adaptation, stability and plasticity

In this section definitions related to adaptation and plasticity are explained. Hill *et al.* (1998) define adaptation as a genetic change, which is an evolutionary process guided by selection. Adaptation involves one or several characteristics, which are advantageous to a variety or population under particular conditions (Sultan, 1995). Such characteristics can be resistance to diseases or pests, nitrogen efficiency, daylight sensitivity or tolerance to heat, cold, drought, water logging, salt, soil acidity, wind, etc.

Breeders often use terms such as 'phenotypic stability' and 'yield stability' to indicate the ability to resist change, or in the case of yield, to show little variation in yield under different conditions, while the genotypic composition of a variety or population remains unaltered (Hill *et al.*, 1998). Stability can also be called wide or broad adaptation (Simmonds, 1991), which is often used in the literature instead of stability (Ceccarelli, 1989; 1994; Hawtin *et al.*, 1997). Wide adaptation or yield stability in crop varieties can be achieved in two ways: through genetic variation within varieties or through phenotypic plasticity.

Phenotypic plasticity is the ability of an organism to alter its physiology or morphology in response to changes in environmental conditions (Schlichting, 1986; Hill *et al.*, 1998). The phenotype of a particular variety may differ greatly among very different environments, while its yield remains relatively stable. Genotypes cannot be classified as more and less plastic, because the level of phenotypic variability across environments can vary between traits of the same individual (Scheiner, 1993). It is important to distinguish two different types of phenotypic plasticity: inevitable plasticity and functionally adaptive plasticity (Sultan, 1995). Under unfavourable conditions, plants inevitably show reduced growth, which is rather the result of inevitable plasticity. Plants subjected to different water regimes developing different root systems is an example of functional adaptive plasticity. Often, however, the response of traits will be simultaneously inevitable and adaptive. So, phenotypic changes associated with different environmental conditions cannot automatically be assumed to represent adaptive plastic adjustment (Sultan, 1995).

Genetic variation is positively related to stability, because different genotypes perform well under different conditions, resulting in a stable overall performance. Landraces are considered to be more stable because they are more diverse. In Chapter 7, however, it was suggested that diversity within landraces might differ between crops and farming systems. Genetically uniform varieties rely on phenotypic plasticity or 'individual buffering', while heterogeneous varieties can rely on both phenotypic plasticity (individual buffering) and population diversity (populational buffering), cf. Allard and Hansche (1964).

Effect of pollen flow and selection

Consequently, adaptability is likely to differ for cross- and self-pollinated crops. Compared to self pollinating crops, cross-pollinating crops can rely much more on populational buffering. To what extent self-pollinating crops can balance their limited populational buffering with individual buffering is not clear, however. It is likely that this depends on physiological plasticity, which may also vary among the various cross- and self-pollinating crops. In contrast to what was often thought in the 1960s and '70s, there seems to be no or little relationship between the level of plasticity and heterozygosity. Instead, plasticity seems to be caused by additive and epistatic effects (Scheiner, 1993).

The level of individual buffering also depends on the direction and nature of environmental selection pressures. Mather (1973) indicates that selection over time induces plasticity of populations, while selection over space induces divergence of populations. However, if individuals are sufficiently plastic to produce phenotypes suited to more than one environment, adaptive population differentiation may be obviated (Sultan and Spencer, 2002). Spatial disruptive selection favours more precise specialisation, and thus local adaptation, and consequently can lead to an increase in genetic variation at the crop or species level (Hill *et al.*, 1998). Cyclical disruptive selection in time does not favour genetic diversity within a population, but rather results in more plastic genotypes in that population (Mather, 1973; Hill *et al.*, 1998). It is also possible, however, that under varying conditions populations maintain genetic variation, because different genotypes will have a higher fitness under different conditions (Sultan, 1995). So, the varying of environmental conditions typical of marginal low-input farming systems may not favour specific local adaptation (Hardon and de Boef, 1993).

11.2 Materials and methods

In each of the villages Tujereng, Kitti, Faraba and Janack millet seed was obtained from one farmer and was used to set up four trials in each of these four villages. For each trial, a design with four rows and four columns was used (Figure 11.1). The seed lots from Kitti and Janack belonged to the same white variety. It was only after the morphological analysis (see Chapter 10) that it became clear that the seed lots from Faraba and Tujereng were from two different black varieties. All four seed lots were also included in the trial for morphological analysis of diversity, as described in Chapter 10. In Tujereng the trial was completely researcher managed, while the trials in the other three villages were set up in the fields of the farmers from whom the seed was obtained with all activities under farmer management except the set up and thinning of the trials.

Tujereng	Faraba	Janack	Kitti
Janack	Tujereng	Kitti	Faraba
Kitti	Janack	Faraba	Tujereng
Faraba	Kitti	Tujereng	Janack

Figure 11.1: Trial set-up used in each of the villages Tujereng, Kitti, Faraba and Janack. Names in the above scheme refer to the seed lots (each obtained from one of the four villages).

Because of differences in farmer management and - possibly more important - because of erratic rainfall in 2002, trial conditions differed widely. So, even though edaphic and climatic conditions did not differ a lot between the four villages, the trials did differ because of variation in rainfall patterns, sowing dates, soil fertility, weeding, soil preparation and plant distances. The trials in Faraba and Tujereng were sown earliest, but because of erratic rainfall, it took a while before good field establishment was obtained, even though the trials were weeded in time and soil fertility was relatively good (No soil analysis was performed because of technical problems at the soil laboratory of NARI). The trial in Janack germinated very well, but due to a delay in rain, late weeding and poor soil fertility, plants did not grow well in the later phase. The trial in Kitti was sown late, mid August (early July is the normal time of sowing), and shortly after weeding the whole field was completely grazed by cows, but because of good soil fertility plants were quick to recover. In Faraba, where the field was not ploughed, plant density was higher than in Tujereng and Janack, where the fields were ploughed with oxen. In Kitti the field was ploughed by hand, which resulted in bigger ridges and wider spacing. The trial in Faraba ripened first, followed by Tujereng, Janack and Kitti.

Usually, the level of adaptation is quantified by measuring yield, or yield components. For millet, yield can be described in terms of the following components: # spikes per plant x (# grains per plant / # spikes per plant) x 1000 grain weight. Unfortunately, because of problems with the seed counting machine at NARI, it was deemed impractical to measure 1000-grain weight and number of grains per plant. For that reason, yield, spike length, spike width and number of spikes were measured. To get a better understanding of the behaviour of these traits, other traits that do not have an obvious or direct relationship with adaptation were also measured, which are plant height, leaf length and leaf width.

Yield was measured at plot level. For the traits number of spikes / plant, spike length, spike width, plant height, leaf length and leaf width, five plants per plot were selected at random and were measured, resulting in 20 plants per seed lot per trial. Because of a second visit by cows just before harvesting, no yield data are available for Kitti.

11.3 Results

Figures 11.2-11.7 show the average values for the measured characteristics. The x-axis shows the four trial sites and, from left to right, the means are given for the seed lots from Faraba, Kitti, Tujereng and Janack. The results show that the traits responded differently to the different conditions in the four trials. Spike length and width are very stable over all four sites, whereas yield and number of spikes / plant varied most among sites. The four seed lots responded in similar ways for all traits, except for leaf length and leaf width.

Figures 11.2 and 11.3 show that yield and number of spikes / plant differ between sites, but there are no differences between seed lots. The reason yield is not significant (Table 11.1) for trial sites is the rather large variation within each trial site. Number of spikes per plant differs significantly between sites, but not between seed lots. In Tujereng the number of spikes per plant is highest, while in Janack it is lowest. Among the measured traits, the correlation between yield and number of spikes per plant is highest (Table 11.2), which suggests that number of spikes per plant contributes most to yield. It is likely that number of spikes, and consequently also yield, clearly responds to soil fertility (The Tujereng trial has the best soil fertility, followed by either Faraba or Kitti, with Janack last) and possibly other factors like time of sowing and weeding.

Spike length and width do not show any differences between trial sites, but do show differences between seed lots (Figures 11.3 and 11.4). Table 11.1 shows that among all traits, spike length and spike width have the largest F-values for seed lots, but the smallest for trial sites. Even in Kitti, where plants were induced to flower more quickly (since they were sown much later), spike length and width do not differ from the other villages. This means also that the time of sowing, and consequently the number of days between sowing and flowering, seem to have no influence on spike length and width.

Leaf length and width differ significantly between sites (Table 11.1). Leaf width also differs significantly between seed lots (Table 11.1). Figure 11.7 shows that all seed lots have the widest leaf in Tujereng and that the seed lot from Tujereng has the widest leaf. Figure 11.6 shows that all seed lots have the longest leaf in Faraba and that in Faraba the seed lot from Faraba also tends to have longer leaves than the other seed lots (though this is not statistically significant).

Plant height shows a significant seed lot × trial site interaction and also shows clear differences between sites. Plant height does not show patterns similar to leaf length and leaf width (Figure 11.8). The reason that plant height is shorter in Kitti than in Janack, although soil fertility was better in Kitti, is that late millet is photo-period sensitive and the millet was sown much later in Kitti than in the other 3 villages.

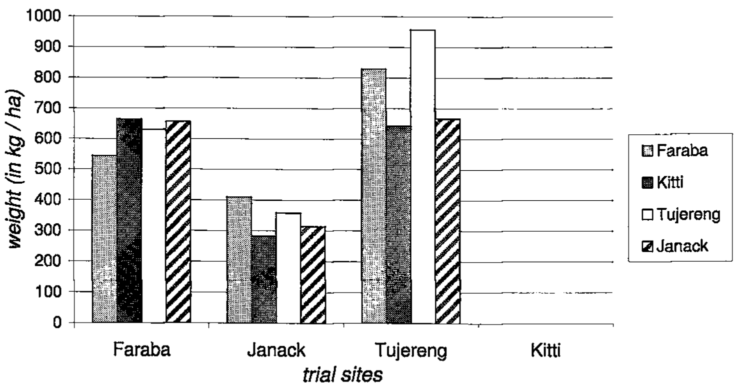


Figure 11.2: Average yield per millet seed lot in each of the trials (legend shows the sources of the seed lots).

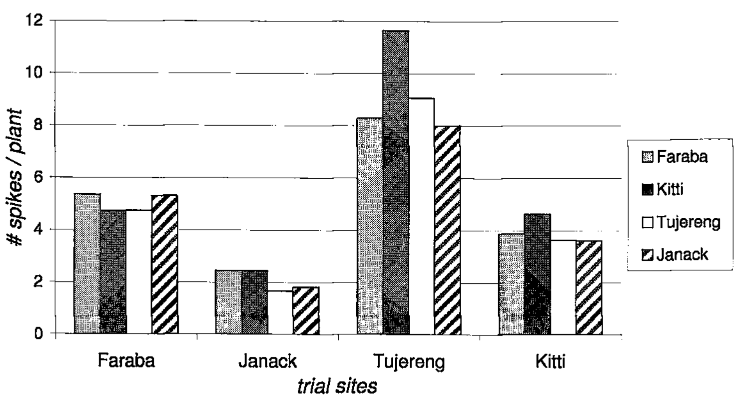


Figure 11.3: Average # spikes / plant per millet seed lot in each of the trials (legend shows the sources of the seed lots).

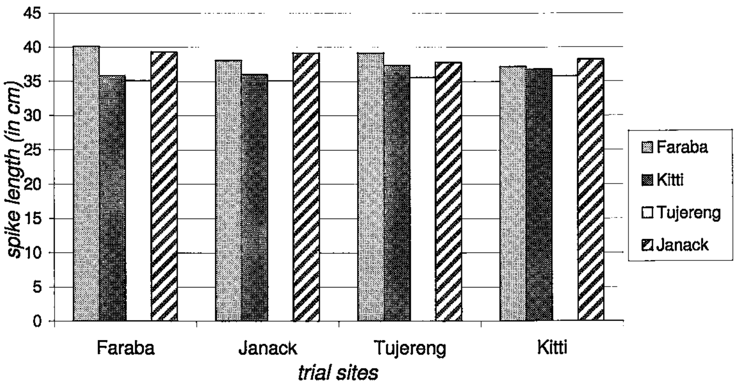


Figure 11.4: Average spike length per millet seed lot in each of the trials (legend shows the sources of the seed lots).

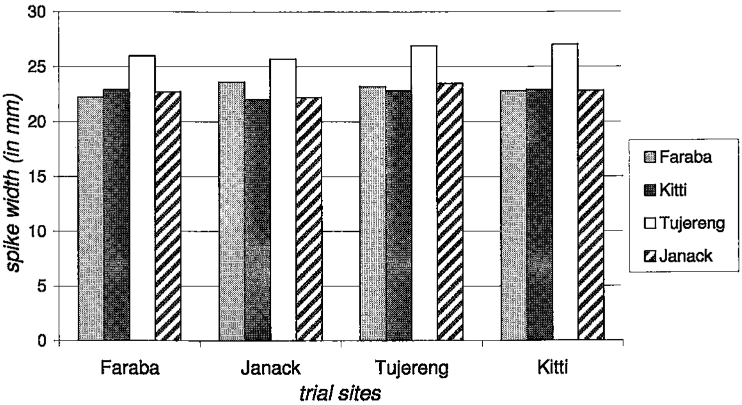


Figure 11.5: Average spike width per millet seed lot in each of the trials (legend shows the sources of the seed lots).

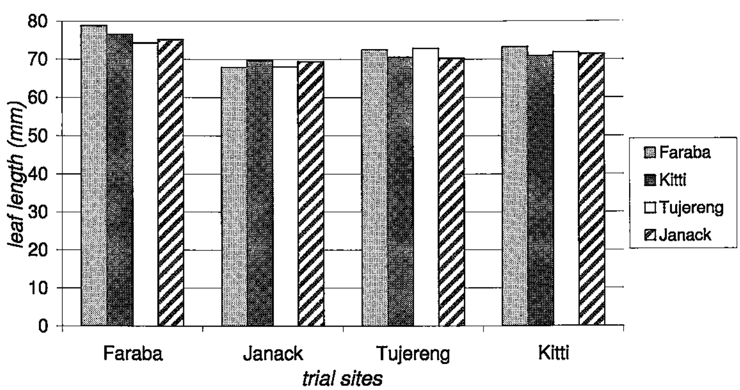


Figure 11.6: Average leaf length per millet seed lot in each of the trials (legend shows the sources of the seed lots).

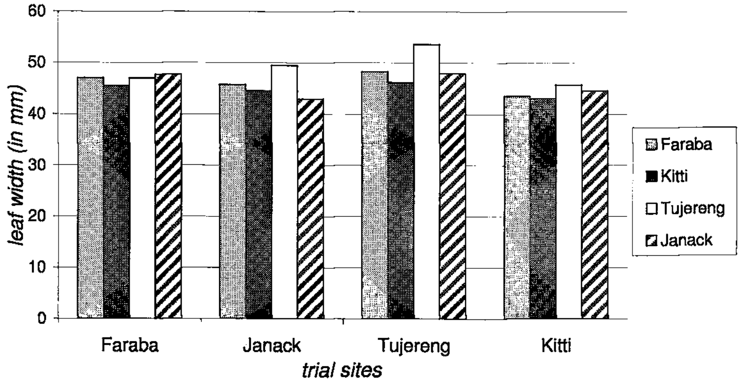


Figure 11.7: Average leaf width per millet seed lot in each of the trials (legend shows the sources of the seed lots).

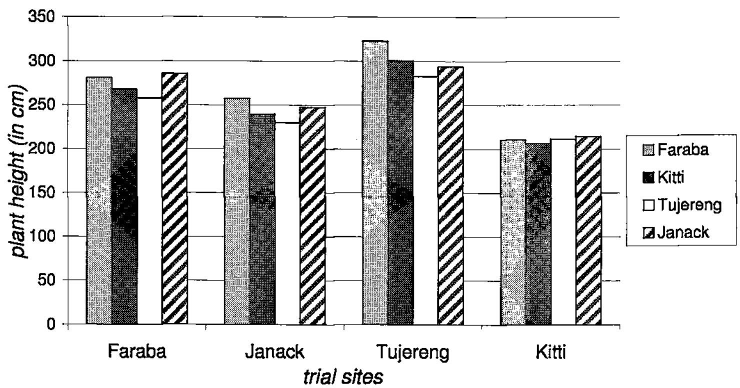


Figure 11.8: Average plant height per millet seed lot in each of the trials (legend shows the sources of the seed lots).

Table 11.1: Significance levels (p) and F-values for various traits of late millet comparing 4 trial sites and 4 seed lots, based on ANOVA.

	seed lot		*trial site*		*seed lot x trial site*	
	p	F	p	F	p	F
yield	0.704	0.5	0.055	6.3	0.364	1.2
# spikes / plant	0.261	1.6	0.013	68.2*	0.334	1.2
spike length	0.003	9.9**	0.744	0.5	0.695	0.7
spike width	0.000	29.4***	0.488	0.9	0.861	0.5
leaf length	0.226	1.7	0.008	7.9**	0.572	0.9
leaf width	0.035	4.4*	0.046	4.6*	0.345	1.2
plant height	0.040	4.2*	0.000	18.8***	0.008**	3.5

* Correlation is significant at the 0.05 level
** Correlation is significant at the 0.01 level
*** Correlation is significant at the 0.001 level

Table 11.2: Correlations based on plot averages using 2-tailed Pearson correlation test (N = 63, except for yield N = 47).

	leaf length	leaf width	plant height	# spikes / plant	spike length	spike width
yield	0.200	0.410**	0.643**	0.650**	-0.095	0.347*
leaf length		0.181	0.243	0.138	0.333**	0.046
leaf width			0.386**	0.347**	-0.011	0.403**
plant length				0.636**	0.242	-0.033
# spikes / plant					0.007	0.027
spike length						-0.164

* Correlation is significant at the 0.05 level (2-tailed)
** Correlation is significant at the 0.01 level (2-tailed)

Data from other trials

Table 11.3 shows a comparison of six millet seed lots of one variety (*white sanyo*) over two years, as also used in Chapter 4. The F-values for year-effect of spike length, spike width and leaf width are much smaller compared to the values for the other characteristics. This is similar to the pattern found for the adaptation trial described above. For this trial 1000-seed weight was measured, which also shows a very low F-value for year-effect. This suggests that, like spike length and width, 1000-seed weight is not influenced by different environmental conditions.

Table 11.3: Significance levels (p) and F-values for various traits of late millet comparing 6 seed lots of 1 millet variety (*white sanyo*) over 2 years, based on ANOVA.

	seed lot		*year*		*seed lot × year*	
	p	F	p	F	p	F
yield	0.525	0.9	0.008	16.7**	0.164	1.7
# spikes / plant	0.787	0.5	0.001	57.2***	0.416	1.0
spike length	0.304	1.6	0.103	4.2	0.123	1.9
spike width	0.088	3.7	0.414	1.8	0.507	0.9
1000-seed weight	0.390	1.3	0.663	0.2	0.308	1.3
leaf length	0.769	0.5	0.006	20.0**	0.089	2.2
leaf width	0.619	0.8	0.143	3.4	0.086	2.2
plant height	0.813	0.4	0.001	70.7***	0.032	3.0*
separation	0.569	0.9	0.001	82.0***	0.416	1.0
stem diameter	0.427	1.2	0.008	14.0**	0.049	2.6*
DAS to 50% flowering [1)]	0.319	1.6	0.000	294.8***	0.056	2.6

[1)] = # days between sowing to 50% flowering
* Correlation is significant at the 0.05 level
** Correlation is significant at the 0.01 level
*** Correlation is significant at the 0.001 level

Similar analyses were done for rice, comparing, respectively, 8 (from cluster II, Figure 10.4) and 6 (from cluster III, Figure 10.3) varieties over two years (Tables 11.4a and 4b). These are the same varieties used to calculate heritability estimates in Chapter 4. The inflorescence related traits of rice seem less stable than those of millet. Panicle length of rice, which has a similar function as spike length for millet, shows year effects (particularly in Table 11.4b), whereas spike length for millet does not. Seed width of rice shows a very low F-value for year effect for the varieties from cluster II (Table 11.4a), similar to spike length and spike width for millet, but the F-value for year effect for the varieties from cluster III is within the range of F-values for the other traits (Table 11.4b). Seed length was measured less accurately the first year, and, consequently, was excluded from the analysis. The 100-seed weight of rice has the largest F-values for variety effect, but does not have the small F-value for year effect that 1000-seed weight has for millet.

Comparison of the F-values for year effect from Tables 11.4a and 11.4b suggests the varieties from cluster III (new farmer varieties) are more adapted to the current climatic conditions than the varieties from cluster II (old farmer varieties). This agrees with farmers' observations.

Table 11.4a: Significance levels (p) and F-values for various traits of upland rice comparing 8 varieties (from cluster II, Figure 10.3) over 2 years, based on ANOVA.

	variety		*year*		*variety × year*	
	p	F	p	F	p	F
plant height	0.015	6.1*	0.004	17.6**	0.631	0.7
leaf length	0.002	11.2**	0.000	41.4***	0.946	0.3
leaf width	0.177	2.1	0.000	45.1***	0.340	1.2
ligule length	0.186	2.0	0.024	8.2*	0.191	1.5
DAS to 50% flowering [1)]	0.007	7.8**	0.000	161.6***	0.086	2.0
# panicles / plant	0.446	1.1	0.001	30.0***	0.314	1.2
panicle length	0.024	1.7*	0.026	7.8*	0.453	1.0
seed width	0.003	10.5*	0.058	5.1	0.059	2.2
100-seed weight	0.000	107.4***	0.000	165.0***	0.991	0.1

[1)] = Days after sowing till 50% of the plants flower
* Correlation is significant at the 0.05 level
** Correlation is significant at the 0.01 level
*** Correlation is significant at the 0.001 level

Table 11.4b: Significance levels (p) and F-values for various traits of upland rice comparing 6 varieties (from cluster III, Figure 10.3) over 2 years, based on ANOVA.

	variety		*year*		*variety × year*	
	p	F	p	F	p	F
plant height	0.081	3.9	0.156	2.8	0.501	0.9
leaf length	0.087	3.7	0.047	6.8*	0.711	0.6
leaf width	0.035	6.0*	0.099	4.1	0.164	1.8
ligule length	0.129	3.0	0.116	3.6	0.212	1.6
DAS to 50% flowering [1)]	0.067	4.3	0.000	107.4***	0.298	1.3
# panicles / plant	0.039	5.7*	0.043	7.1*	0.632	0.7
panicle length	0.053	4.9	0.005	23.2**	0.344	1.2
seed width	0.000	218.8***	0.059	5.8	0.710	0.6
100-seed weight	0.000	740.7***	0.000	95.5***	0.983	0.1

[1)] = Days after sowing till 50% of the plants flower
* Correlation is significant at the 0.05 level
** Correlation is significant at the 0.01 level
*** Correlation is significant at the 0.001 level

11.4 Discussion

Adaptation at field level

The data on millet suggest that yield and number of spikes per plant are less stable traits than spike length and spike width. When all four sub-trials are combined, there are clear correlations between yield, spike number and plant height. The highest plants tend to produce more spikes and consequently contribute more to yield. Lower correlations exist between yield and, respectively, leaf width and spike width. So, spike width and spike length contribute little to yield. The implications for farmer seed selection are discussed below. The four millet sub-trials show the largest differences for tillering. Differences in tillering can be very large for rice, depending on the cultivation methods used (Stoop, 2002). This is related to the fact that the number of tillers increases exponentially instead of linearly during phyllochrons (Stoop, 2002). A phyllochron represents a periodicity in plant growth of gramineae species expressed as a number of days, in which nodes and tillers develop. The better the growth conditions the shorter the phyllochron and the more tillers develop (in an exponential way) on one plant in a certain period of time. Under good growth conditions plants do not only tiller profusely but also grow taller, flower later, and yield higher (Stoop, 2002). This, it seems, likely explains the high correlations between yield, plant height and spike number found in this experiment for millet. It also means that adaptation is related to the existence of genetic variation for the duration of the phyllochron in millet.

The variation in yield within and between trial sites underlines the somewhat surprising absence of differences in spike length and spike width within and between trial sites. This indicates that spike length and width are less influenced by environmental conditions than the other traits, which suggests that spike length and width respond in a more stable way to environmental variation than the other characteristics. Possible explanations for the absence of differences in spike length and spike width between sites are the rapid development of reproductive structures compared to tillering and, secondly, that the spike develops at a later stage than tillering (Stebbins, 1950, in Bradshaw, 1965). As each elongated tiller produces one spike and elongated tillers of one plant do not differ that much in size, a plant with 10 tillers can produce about 10 times as much energy as a plant with only one tiller. Another point is that millet plants develop roots up to a length of 1 m and ensure a sufficient nutrient uptake for the development of the inflorescence. This means that the small differences in spike length and width between sites, compared to the other characteristics, are likely based on the plasticity of morphological and physiological traits important in earlier stages of development and does not necessarily mean that spike length and width itself are more stable than the other characteristics. This suggests that the level of adaptation of a millet variety needs to be assessed both by measuring plant traits related to the early vegetative stage, such as tiller number or total leaf area, and by measuring traits related to the inflorescence, such as spike length and spike width.

In general, traits related to the reproductive capacity are often very stable in order for the species to survive (Bradshaw, 1965; Allard, 1988; Sultan; 1995). However, there are also exceptions, like *Impatiens capensis*, for which differences in flower number between sites were in the same range as the vegetative traits (Schmitt, 1993). Whereas spike length and width of millet seem very stable traits, panicle length of rice seems less stable. This suggests that different species of the gramineae family behave differently, which may be related to differences in plant morphology of rice and millet. It is also reported that even within the same species different genotypes can show different plastic responses (Bradshaw, 1965). This might also explain the various variety × year interactions for rice.

Farmer seed selection

In Chapter 4 wide sense heritability estimates were calculated for the various measured traits of millet and rice. Heritability estimates on the basis of two years or four locations indicated for millet that spike length and spike width have the highest levels of heritability, while yield and spike number are among those characteristics with the lowest levels of heritability. This suggests the best way to improve millet populations is through selection for spike length and width. The information in this chapter, however, suggests that the stability of spike length and spike width is based on morphological traits and physiological processes important in earlier phases of plant development. This, then, implies that the heritability estimates are actually too high for traits like spike length and width. This means that the efficacy of selection for long and wide spikes will be less than might be assumed on the basis of heritability estimates.

Spike number, on the other hand, seems to respond more in an inevitable plastic way to the growth conditions than spike length and width. Thus spike number seems to reflect better the actual genetic potential of plants than spike length and width. Depending on the value of heritability estimate for number of spikes per plant, selection advances might be reached through selection for spike number, rather than for spike length and spike width.

Farmers who select for both vegetative and reproductive characteristics thus have a larger influence on the genetic make up of a population than farmers who only select for characteristics related to the inflorescence. This might help explain why in a study conducted by Smith *et al.* (2001), in which farmers selected for both vegetative traits (particularly cob number) and traits related to the cob, selection in farmer varieties of maize showed an improvement in yield, whereas in a study conducted by Soleri *et al.* (2000) farmer selection in maize, but only on traits related to the cob, did not show any improvement.

Comparing rice and millet, it seems that panicle length of rice responds in a more plastic way than spike length and width of millet. Since there is no farmer selection in rice on panicle length, while there is in millet for spike size, the question arises whether farmer selection affects the stability of spike length and width. There is evidence that selection for plasticity and stability is possible (Scheider, 1993; Schlichting, 1986).

From the morphological analysis in Chapter 10 it was concluded that the seed lots from Janack and Kitti belong to the same variety. But Table 11.4 shows that in all four trial sites the seed lot from Kitti has a (significantly) shorter spike than the seed lot from Janack. Based on this information, it can be hypothesised that farmer selection does have some effect on spike length and width, albeit small. To achieve a better and more conclusive understanding of the effects of farmer selection, and to avoid the pitfalls of G × E interactions, recombination, epistasis and the like, it would be best to set up experiments over a longer period of time (at least 5 to 10 generations).

Local adaptation

The experiment described in this chapter indicates that in a relatively flat country, with small differences at the regional level in climatic, edaphic and other environmental factors, big differences exist at field level. These are caused by differences in access to land, fertiliser application (both organic and inorganic), ploughing equipment and labour. Since these factors can differ for each farmer from year to year (although for one farmer more than for the other) and also because rainfall varies a lot from year to year, it is logical that millet populations do not become narrowly adapted in The Gambia, but rather develop large levels of plasticity as is outlined by Mather (1973) and Hill *et al.* (1998). The results on leaf width and leaf length agree with this. In Tujereng all populations developed significantly wider leaves than in the other villages and in Faraba all populations developed significantly longer leaves. The position of Tujereng, near the coast, where winds are harder and more frequent, might explain why the millet populations grew wider leaves in Tujereng than in the other villages. It is difficult to explain, however, why the populations grew longer leaves in Faraba. Whereas in nature, local adaptation has been observed at scales less than 1 m (Linhart and Grant, 1996), agriculture may promote the evolution of plastic genotypes over locally adapted genotypes (Sultan and Spencer, 2002).

As suggested in the introduction and confirmed in this experiment, there must be clear local environmental stresses before varieties will become adapted to very local conditions. This would mean that in The Gambia most varieties of most crops are widely adapted. In more mountainous or otherwise more diverse countries, it is much more likely that farmers need locally adapted varieties. In Nepal, where extreme temperature regimes exist, rice varieties need to be adapted to those extreme conditions, leading to local adaptation (Joshi *et al.*, 2001). However, in the Peruvian Andes, the wide range of potato varieties grown by farmers are not specifically adapted to niche environments, but are all grown mixed in the same field (Zimmerer, 1998; Brush 1995). Because environmental conditions change in an unpredictable way from year to year only plastic potato varieties can survive (Zimmerer, 1998).

Variety choice

Whereas it can be safely concluded that the choice for late millet varieties instead of early millet varieties is based on agro-ecological factors, the choice for either black seeded or white seeded millet varieties in the four villages is more likely to be the outcome of a social process, given the results of this chapter. For many farmers, the main reasons to grow a particular variety are taste and processing qualities rather than the agricultural qualities. In Tujereng and Faraba people prefer black millet, whereas in Janack and Kitti people prefer white millet because of differences in taste and processing. Traditionally, Mandinka grow black millet and Jola grow white millet. Adaptation may also play a role in variety choice, i.e. farmers may grow a particular variety because they like the taste of that variety better but they might equally have adapted themselves to the taste of that variety.

In Chapter 10 it is shown that many of the rice varieties are grown in four 4 villages, but that the most commonly grown varieties are different for each of the four villages. All these common varieties were grown in a small yield trial in Tujereng over two years, but no clear yield differences were observed, except for the variety Baraso which is the common variety in Faraba (see Appendix 4). So, apart from this variety, it seems that the other varieties are common not so much because of agronomic performance and adaptability, but perhaps more because of social processes associated with variety testing and exchange. This suggests that many of these rice varieties are widely adaptable. Unfortunately, no rice trials were conducted in all four villages to substantiate this assumption. In Chapter 3 it was shown that the soil conditions differ slightly between the four villages, but not much. In Tujereng rainfall is somewhat more reliable than in the other three villages (see Chapter 2).

Important factors determining the popularity or wide acceptance of a variety may be the time of introduction, the diffusion rate of that variety and the presence and popularity of other varieties. This, in turn, might mean that the fact that different sets of rice varieties to be found in the four villages is a product of these other factors rather than by farmers matching genotypes with environments at a very local level. This information can be used to optimise dissemination of formal varieties over large areas. If, in a village the difference between existing and new varieties is very big, the new variety may be quickly adopted, while if the difference is relatively small, the new, slightly better yielding variety might not be adopted at all. The issue, for technologists, is to adapt introductions to the state of play - to inject valuable varieties into a complex, ongoing productive 'dance' (Richards, 2005).

In the lowland ecologies in The Gambia, where conditions differ more, and salinity, acidity and iron toxicity are general problems, local adaptation likely plays a more important role. In the case of cassava in the Amazon basin in Peru, the isolation of farming communities helps to maintain differences in cassava variety choice between villages, whereas there are no clear agro-ecological differences between these villages (Salick *et al.*, (1997). It is also possible that varieties are different for traits not related to plasticity and adaptation but share patterns of adaptive plasticity (Sultan, 1995). Local adaptation will only occur if there is a need. If there are no niches, there will not be any local adaptation. Drawing a parallel to morphogenesis, as described by Goodwin *et al.* (1993), a variety can also be described as the result of several adaptation processes to different variables. This leads to a relatively limited number of variety classes, instead of a continuum of varieties each adapted to slightly different conditions. Then the question is in what way adaptations to specific factors interact with each other and which of these adaptations can be combined in crop varieties. In this context, one should think of adaptations to diseases or pests, nitrogen efficiency, daylight sensitivity, or tolerance to heat, cold, drought, waterlogging, salt, soil acidity, wind, etc.

11.5 Conclusions

The following conclusions can be drawn:

- All tested millet varieties seemed to respond in similar ways to different ecological conditions.
- Spike length and width are very stable under different ecological conditions, which is the likely result of morphological and physiological plasticity of other traits. It is likely that the heritability estimates for spike length and width are over-estimations and that farmer selection might be more effective if other traits, like spike number per plant, are considered.
- There is no local adaptation at village level for late millet in The Gambia.
- It is plausible that local adaptation does not play a role for rice in the case study villages.
- Local adaptation only plays a role when there are clear ecological stresses.
- In this study, variety choice of millet is apparently more the result of social processes, chance or factors unknown, than of ecological adaptation.

12 Summary, conclusions and thoughts on strengthening the system

12.1 Introduction

The objective of this study was to get a better understanding of local gene flow and its effects on crop genetic diversity (i.e. availability, genetic make-up and diversity of varieties) and as such on the farming system as a whole, and whether these effects are related to or influenced by breeding system, gender, farmer selection, or possibly other agricultural practices, socio-economic factors or cultural understandings, consciously or tacitly.

The three main research questions that follow from this objective were:
1. How is gene flow managed by farmers and which factors play a crucial role?
2. What is the impact of gene flow on the adaptability and resilience of the farming system?
3. Based on the answers to questions 1 and 2, what suggestions can be made to integrate formal and informal crop improvement?

Chapters 2 to 9 gave partial answers to the first main question. In this chapter, the concluding chapter, these partial answers are brought together and the short formula on gene flow, presented in Chapter 1, will be further elaborated. With this information, and information from Chapters 10 and 11, the second research question will be answered. Then, with these answers in mind, the comparison of scientific and farmer breeding in Chapter 1 will be further elaborated. Subsequently this information will be used to illuminate the third question through some suggestions on how formal and informal crop improvement might be better integrated.

12.2 Management of gene flow

In the introduction gene flow was defined schematically as follows:

Gene flow = (seed flow + pollen flow) * selection pressure

In the following section this formula will be elaborated, as is shown in Figure 12.1. First, each component is dealt with separately.

Selection pressures

Chapter 4 elaborated on selection pressures within varieties, while Chapter 5 dealt with selection between varieties. From data in Chapter 4 it became clear that the differences between seed lots of the same varieties are small for millet, and almost non existent for rice. In the case of rice, selection within varieties is practically impossible because of the large numbers of panicles needed for seed, and, secondly, because rice is an inbreeding crop with little genetic variation within populations. For millet, selection within varieties is possible, but probably has very little effect in terms of improvement because of the varying conditions from year to year and, secondly, because of the rather large numbers of spikes (up to 1000) selected for seed. Furthermore, because environmental conditions do not differ much between different areas in The Gambia, natural selection pressures only have small divergent effects on millet populations.

As indicated in Chapter 5, there are many more rice varieties than millet varieties. Women, on average, grow three varieties of rice, whereas men usually grow one millet variety. These

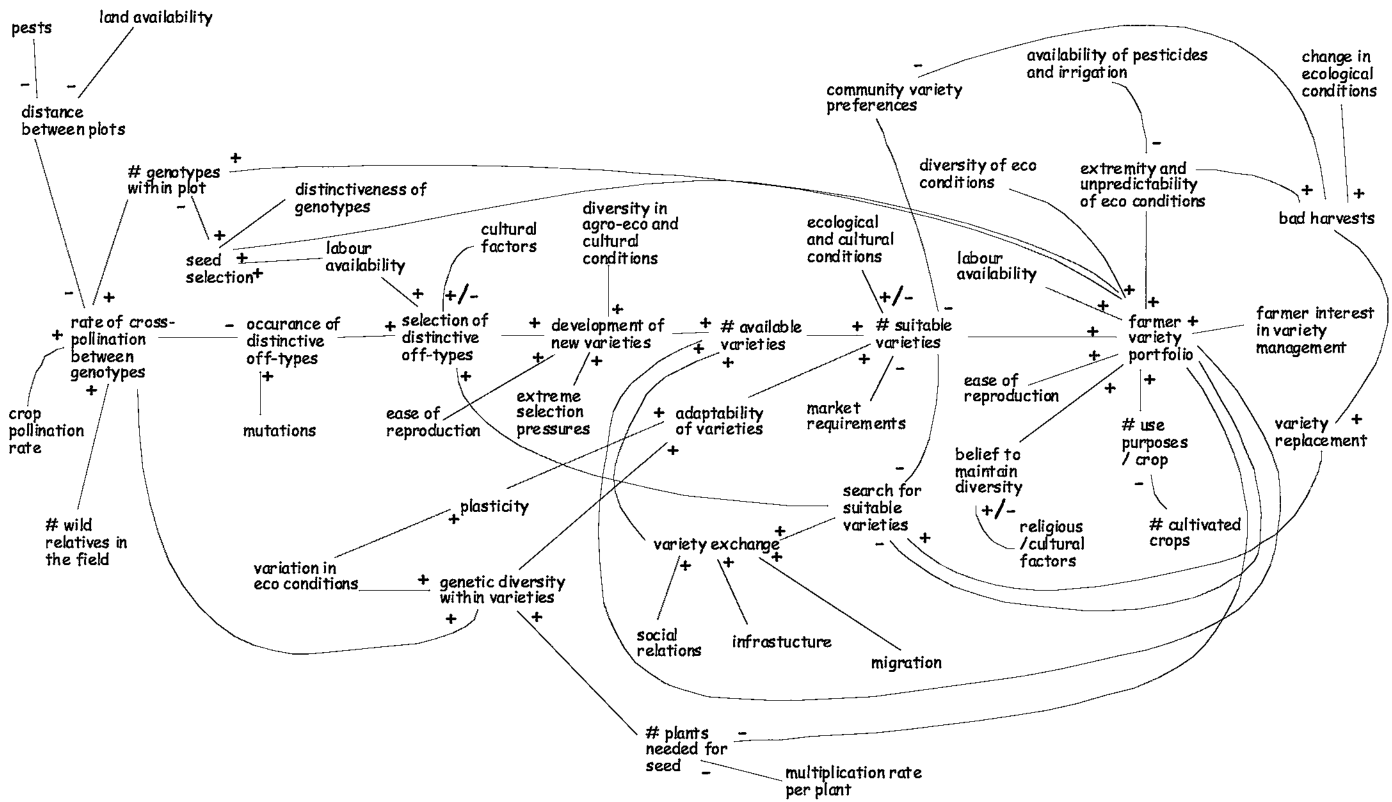


Figure 12.1: Elaborated scheme on the various factors related to gene flow.

differences can be explained by difference in breeding system (see under pollen flow), ecological complexity and number of variety selection criteria. Another factor seems to be that whereas women mainly grow rice during the rainy season, men grow a range of crops because of which they only grow, on average, one millet variety. The difference in varietal diversity seems largely unrelated to gender-based skill factors (under this assumption it being argued that women are better in variety management as a result of which more rice varieties exist than millet varieties). From the grouping exercise in Chapter 9 it can be concluded that men and women manage varieties similarly.

The real basis of the difference seems to lie with the two crops themselves. In rice, selection between varieties is done quite frequently and has a bigger impact in terms of improvement than selection within varieties, while for millet, selection between varieties does not occur frequently and selection within millet varieties has some impact (although it is not clear how much). As a result, rice improvement is more of a stop-and-go process and millet improvement is more a gradual and smooth process. Women do what works for rice, and men do what works for millet.

Seed flow

Farmers clearly attempt to manage seed flow. This was the topic addressed in Chapter 6. The chapter shows that various factors influence and determine seed flow. The main factors regulating seed flow are seed loss, need for new varieties (related to change in environmental, socio-economic and cultural conditions) and the existence (or absence) of channels through which seed can flow. In a traditional farming system these channels are kinship lines, friendships, trade relations and markets. Nowadays, the formal seed sector is an extra channel, although through this channel seed flows only in a one-way direction (from the formal sector to farmers). Seed flows between villages are more common for rice than for millet. Because about one third of the women marry outside their village, these links to family in other villages is an important channel for rice seed flow between villages, whereas in the case of millet, cultivated by men, there is very little seed flow between villages. Another explanation for the limited millet seed flow is that there are very few millet varieties compared to rice varieties and thus there is less need for seed exchange between villages.

For rice, most seed flow between villages is meant for the testing of new varieties. Most rice seed flow within villages is geared towards replacing lost seed stocks. For millet, both seed flow within and between villages are primarily for the replacement of lost seed stock. Variety naming provides information about the level of variety flows. In those villages where rice varieties have common names there may be less seed flow with other villages than in villages where rice varieties lack common names. Variety names also give information about the age and commonness of varieties, for both rice and millet.

Related to seed flow, and more importantly, to the effect of seed flow, are the number of varieties that exists and the number of varieties used by farmers (see Chapter 5). The more varieties that exist, the more seed flow and more variation in seed flow between villages. The factors influencing variety use and the number of varieties that exist for a particular crop are: extremity and unpredictability of environmental conditions, diversity of environmental conditions, total number of crops grown by farmer, number of uses of the crop, importance of the crop, crop breeding system, ease of reproduction, labour organisation and market organisation. Various socio-economic and cultural factors influence seed flow, with both positive and negative effects on genetic diversity, depending on the context. An example is the impact of increased rice imports and the increased perception that *O. glaberrima* is difficult to pound on the reduced seed flow of *O. glaberrima*, as explained in Chapter 5.

Pollen flow

Compared to seed flow, pollen flow is not consciously managed by farmers. Chapter 7 shows that pollen flow is very different for rice and millet because of various factors. The most important factor is the rate of outbreeding, millet being an outbreeding crop and rice an inbreeding crop. For pollen flow to result in the development of new genotypes, the level of pollen flow should not be too high. Because of the low rate of cross-pollination in crops like rice, sorghum and beans, new, distinct, stable genotypes develop more easily in these crops than in crops like millet and maize (Figure 12.2). Hence, it is also easier for farmers to select off-types in strong inbreeding crops, and develop them into new varieties, than in strongly outbreeding crops. Other factors determining the chances of the development of new stable genotypes are the distances between fields, the time of flowering, the number of varieties in different fields and the number of mixed-in varieties within fields. Farmers do not mind mixed-in varieties in their seed as they consider it insurance. Because of that, chances of cross-pollination between rice varieties are much higher within fields than between fields. Since within a village almost all farmers grow the same variety of millet chances of pollen flow between millet varieties are very low.

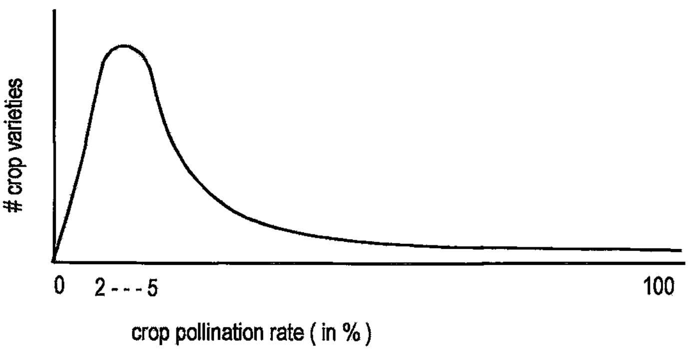


Figure 12.2: Relation between crop pollination rate and the number of varieties developing in farmers' fields.

Chapter 8 shows that, compared to pollen flow between varieties, pollen flow between cultivated plants and wild relatives occurs less frequently (more for rice than for millet) because wild relatives are only found in low numbers in cultivated fields and the wild relatives often flower earlier than the cultivated plants. Furthermore, interspecific pollen flow is less effective because of genetic incompatibility (more for rice than for millet). Farmers manage pollen flow between cultivated crops and wild relatives in an indirect way. Farmers do not care much about wild relatives when they are present in the field in very low numbers, indirectly allowing a little pollen flow. When wild relatives are found in the fields in higher numbers and threaten to outcompete the cultivated crop, farmers weed the wild relatives, reducing pollen flow during flowering.

In general, farmers think off-types are caused by God and they do not have a clear understanding of what exactly causes change in rice and millet. Although men and women have a similar understanding on the development of strange off-types in millet and rice, men have never tried to test strange millet off-types, while women sometimes test and develop strange rice off-types into new varieties. As mentioned above, new stable, distinct off-types develop more easily in rice than in millet. Distinctness of off-types is a requirement for farmers to notice them. The harvesting process enables observations of strange off-types in rice more readily than in millet. Additionally, this study found evidence that it is an aspect of male identity not to test any strange off-types. Men often know how to differentiate varieties, but seemingly this is not knowledge that is important to their self image and to their image within the community.

12.3 Impact of gene flow on adaptability and resilience

The second main research question was whether gene flow plays a role in keeping farming systems adaptable and resilient. Gene flow comprises both seed and pollen flow. As Figure 12.1 shows, seed and pollen flow are interlinked. In Chapter 11 it was elaborated that adaptability (and resilience) can be achieved through genetic diversity and plasticity. In the following sections genetic diversity and adaptation will be discussed in relation to gene flow.

Genetic diversity

In Chapter 10 it was concluded that processes in relation to genetic diversity differ between rice and millet. In the case of rice, pollen flow and farmer off-type-selection have important roles in the development of new varieties. Moreover, for rice, seed exchange between communities is crucial to maintain genetic diversity at village level and regional level, whereas it is less important for millet. In millet it is primarily pollen flow and seed selection through which genetic diversity is maintained.

In Chapter 10 it was also concluded that genetic variation within rice varieties is very low, whereas genetic differences between rice varieties are often large. For millet, genetic variation within varieties is similar to genetic variation between varieties. Consequently, the replacement of varieties generally has a larger impact (both negative and positive) on rice genetic diversity than it has for millet. Also, fewer millet varieties exist than rice varieties, which means millet varieties cannot be often, and consequently are less often, replaced than rice varieties. Hence, it is likely that genetic diversity for rice fluctuates more over time and space than for millet. This is because, in effect, rice genetic diversity is packaged in discrete varieties subject to a great deal of shuffling and scattering. In regard to millet, however, farmers 'swim' in an undulating 'sea' of continuous genetic variation.

One of the questions during the research was whether genetic diversity would decrease or change because of farmers' selection methods. From the information in Chapter 4, it can be concluded that, for rice, farmer seed selection cannot have any impact on genetic diversity within varieties, and for millet, narrowing of the gene pool is unlikely because of the large number of spikes selected for seed and because of cross-pollination in the field.

Cross-pollination among farmer varieties and between farmer and formal varieties may result in genetically new and different farmer varieties (see Chapter 10). For millet, however, it seems that the Gambian late millet farmer varieties constitute a relatively homogeneous genetic group. So, if formal millet varieties are to be introduced (as diverse as the ICRISAT material grown in this study though more suited to Gambian conditions), pollen flow between farmer varieties and formal varieties will be likely to have a bigger impact on genetic diversity than pollen flow among farmer varieties.

It can be concluded that the most important factors related to maintaining genetic diversity are pollen flow, variety exchange, selection between varieties and farmer variety portfolio. Only under particular circumstances, i.e. extreme conditions or very diverse conditions, seed selection and natural selection pressures will have a diversifying effect within varieties. However, these conditions are absent in The Gambia. From the above it follows that gene flow is regulated differently for rice and millet. For rice, the effect of pollen flow and seed flow on genetic diversity shows in the development of new varieties, whereas for millet, seed and pollen flow lead to the maintenance, or in some cases an increase, of genetic diversity at population level.

Local adaptation

Chapter 11 elaborated further on the impact of selection on local adaptation. It shows that millet varieties are not narrowly adapted and that variety choice seems more related to cultural preferences than to local adaptation. Although no data are available, it seems that rice varieties are also quite widely adaptable. For rice, another factor that seems to influence variety choice is the time of introduction of varieties in a village and the range of suitable varieties in that village.

It is probable that at farming system level pollen flow plays a limited role in keeping populations adaptable to rapid environmental changes. This does not mean that the process of adaptation through genetic evolution at field level should be ignored, but that it is too slow a process, compared to the decision making process of farmers who can decide in a few years (sometimes in only one year) to change varieties. In the case of millet, adaptation to lower rainfall levels in the 1970s apparently went too slowly for farmers in the northern part of the country and farmers rather opted for replacing late millet with early millet. So, the decision making process of farmers does not allow time for varieties to adapt to the changed conditions. When conditions change slowly, it seems likely pollen flow plays a greater role, but in the case of rapid changes (such as the decrease in rainfall in the early 1970s) pollen flow plays a limited part because of the speed and efficacy of actions by farmers. It is quite possible that farmers do not even notice slow and incremental genetic changes when presented with much more dramatic shifts such as the Sahelian drought of the early 1970s.

For rice, pollen flow plays an important role through the development of off-types which sometimes evolve into new, better adapted varieties. However, slow changes in rice varieties, theoretically, seem less feasible because of the low rate of pollen flow.

Importance of gene flow

A high cross-pollination rate (as in millet) is likely to be beneficial in keeping varieties adapted to slowly changing conditions. A low cross-pollination rate (as in rice) enables the development of new varieties in the field (see Chapters 5 and 6). Possibly, an intermediate cross-pollination rate (as in sorghum) has the advantages of keeping varieties adapted to slowly changing conditions while still enabling the development of new varieties. This might partly explain the high numbers of sorghum varieties in Ethiopia (cross-pollination rate of 5%, see Doggett, 1988) and bean varieties in Rwanda (cross-pollination rate of 2%, see Voss, 1992).

Obviously, because of fertilisation barriers between species, gene flow between cultivated plants and their wild and weedy relatives occurs less often than among cultivated plants (or among wild and weedy plants). The relevance of this pollen flow is often discussed and generally it is agreed that although it is infrequent it is important in increasing genetic diversity, and helps cultivated species adapt to changing conditions (for example, through conveying disease resistance).

Under slowly changing conditions, a high cross-pollination rate contributes to adaptation at field level, which then in turn contributes to adaptation at farming system level. Under fast changing conditions (whether ecological or socio-economic), seed flows (exchange of varieties) are essential to maintain adaptation at farming system level. A low cross-pollination rate also contributes to the adaptability of farming systems through the development of new varieties (varieties resulting from relatively infrequent cross-pollination are also relatively easily preserved).

Hence, it can be argued that for late millet the process of adaptation is more gradual, while for rice it is more of a stop-and-go process. Whereas late millet populations slowly adapt to the changing climatic conditions in The Gambia, rice varieties tend toward replacement when the 'older' ones do not fit the conditions anymore.

Rice is not well adapted to slow changes because of its low pollination rate (although it can maintain productivity through phenotypic plasticity) but is better adapted to fast changes, because new varieties develop and because women constantly exchange varieties for testing. If there are any fast changes, the infrastructure is in place for women to respond quickly. Millet, however, is better adapted to slow changes, whereas it is (arguably) less adapted to fast changes because men are less used to testing and exchanging millet varieties (which does not mean they find variety testing and exchange alien because they also test and exchange seed of other crops).

However, if there are no 'new' rice varieties to fit the new climatic conditions, like in Janack and other villages, rice farming comes to an end (in Janack farmers stopped growing rice after the droughts of the early 1980s). In the case of Janack, the introduction of 'new' varieties by an NGO was necessary to revive rice farming, after which women used their networks to search for varieties best suited to their ecology.

12.4 Farmer variety development in The Gambia versus scientific breeding

This information allows me to elaborate Table 1.1 (see Table 12.1) regarding The Gambia. In new version of the Table, the choice of parental material is added: whereas breeders choose particular parental materials, often elite lines, farmers do not make any choice at all. Based on the information provided by Simmonds (1989), it can be argued that breeder selection is less efficient for quantitative traits than is usually assumed. It is very efficient for monogenic traits but perhaps only moderately efficient for polygenic traits. On the other hand, farmer seed selection is likely to be less efficient than proposed by Berg (1993). Farmers select new genotypes (off-types) in the first place for their distinctiveness, and only in a later phase they consider performance and various quality traits (see Chapter 7). Hence it is only in later phases that farmer selection can be considered efficient. The information in this thesis suggests that the development of new rice varieties happens very much in a random way, which can lead to the development of potentially useful and valuable new materials, but (perhaps as often) also to the development of genetically similar varieties (see Chapter 10).

Compared to Table 1.1, Table 12.1 in this chapter is more elaborated in terms of breeding strategy: Plant structure, use purpose and disease resistance have been added to adaptation and variation. Breeders define the ideal plant structure based on scientific models whereas farmers select plants that meet local requirements. These local requirements can also change over time (see Chapter 5). Furthermore, farmers can adjust, to some extent, their requirements to accommodate formal varieties. In terms of use purposes, breeders usually emphasise yield and outer appearance, while farmers have a wider range of use purposes in mind, depending on local socio-economic and cultural conditions, which can also change over time (see Chapter 5).

A comparative strength of breeders is that they are efficient in incorporating disease resistances, whereas farmers often do not select for disease resistance, or if they do, they do so coincidentally.

Table 12.1: Differences between scientific breeding and farmer breeding in The Gambia (modified after Berg, 1993).

Plant breeding activity		Scientific breeding	Traditional breeding
Breeding technology	genetic resource base	world genetic resources	locally available genetic resources
	choice of parental material	elite lines	random
	crossings	controlled	random
	selection method (of potential genotypes)	moderately efficient to efficient	random to (moderately) efficient
Breeding strategy	plant structure	based on scientific principles	based on local requirements
	use purpose	emphasise on yield and outer appearance	depends on local socio-economic and cultural conditions
	disease resistance	efficient / often monogenic resistance	random
	adaptation	broad adaptation	(no strategy) depends on ecological circumstances
	variation	uniform varieties	(no strategy) depends on crop breeding system

In terms of adaptation, farmers do not aim to choose or to develop locally adapted varieties. It is often argued that, whereas plant breeders are concerned with wide adaptation, farmers are more concerned with local adaptation (Hawtin *et al.*, 1997). It is true that farmers adopt a new variety when it fits their farming system, and therefore is an issue of adaptation. But whether farmers consider local adaptation of varieties at the field level or select consciously for locally adapted varieties is a question that remains to be answered. From data in Chapter 11 it can be seen that farmer varieties are often rather widely adapted, which can be attributed to varying ecological and climatic conditions over time. Possibly, farmers are much more concerned with adaptation of the farming system. However, it is stated that farmers, particularly in *diverse*, marginal environments in developing countries, continue to breed varieties adapted to their *specific* (italic added twice) circumstances (Hawtin *et al.*, 1997; Teshome *et al.*, 1997). This raises the question as to what extent and under which circumstances such farmers can develop specifically adapted varieties, if their environments are diverse. It may be that some farmer varieties are locally adapted while other varieties grown in the same ecology are broadly adapted. More research is needed to give clearer answers on this issue.

In terms of variation, farmers do not *per se* develop heterogeneous varieties. In the case of rice, farmer varieties are as homogeneous as formal varieties. The fact that farmers select single-plant off-types for the development of new varieties might explain the genetic uniformity. It is possible that in previous work variety mixtures were mistaken for landraces, explaining the common conception that farmer varieties are always very heterogeneous (Cooper *et al.*, 1994; Altieri and Merrick, 1987; Zeven, 1998). The millet varieties in this study are very heterogeneous. So, the level of varietal heterogeneity seems primarily related to the level of outcrossing of a crop: The higher the level of cross-pollination, the higher the level of heterogeneity. One of the main reasons that farmers in The Gambia do not mind mixtures in their field (to a certain extent) is that, in that way, varieties are conserved. In effect, farmers increase the chance of the development of new genotypes, of which they are only partially aware, through this practice.

It can be concluded from this study that farmers do not have a particular strategy to develop new varieties, but rather that they manage the development of new varieties depending on various socio-economic, cultural, ecological and crop-specific conditions. Among the latter, the crop breeding system is particularly important, but factors like seed multiplication rate, number of seeds per inflorescence and ease of harvesting also play a role.

Whereas Gambian farmers do not have a particular strategy in the development of new varieties, they do have clear strategies for variety testing and variety choice. Seed flow is also a more visible process than pollen flow. Hence, the control of seed flow is a conscious process, whereas the control of pollen flow is behavioural. Other studies have also indicated that in different areas farmers often have particular, often different use purposes in mind, and hence, have different variety preferences. It can be concluded that farmers' strengths lie not so much in variety development, which is more of a random process, as in variety comparison and variety selection.

12.5 Strengthening the system

In Chapter 1, a brief outline was given on Participatory Crop Improvement (PCI). It was indicated that Participatory Varietal Selection (PVS) is a good method to select and disseminate varieties that fit farmers' needs better. In PVS farmers participate only in the last stage of variety development: to test which varieties perform best. Less information is available about the potential of Participatory Plant Breeding (PPB) methodologies in which farmers participate in earlier stages of crop development.

In the introduction it was argued that (PPB) could be divided in two approaches. In the first approach, new genetic variation is taken to farmers' fields, in which selection takes place by breeders, or by farmers or by both, leading to the development of new varieties. The second approach is the improvement of already existing varieties in collaboration with farmers. Rice *et al.* (2001) indicated that the second approach of PPB might be useful as an incentive for farmers to continue growing farmer varieties identified as important genetic resources which should be conserved. In the following section the focus is on PCI in relation to crop development and not on *in-situ* conservation.

In this section the third and most important question will be answered using the information collected on The Gambia: How can linkages between scientific and farmer breeding to improve crop development in general be improved? In Chapter 5 the formal seed sector in Gambia was discussed. Formal crop development is taken as an entry point to answer this question. The reason is that for any PCI-activity to be successful, it needs to be linked to the formal crop development system. Even farmer-led PPB, in which scientists seek to support farmers' own crop development, is linked to the formal system through scientists working for NGOs (see Sperling *et al.*, 2001).

Formal crop development

In the case of rice, crop improvement, in general, focuses on irrigated rice and rice grown in rainfed lowlands, but not on upland rice, deepwater rice and tidal wetlands (Dalrymple, 1986). In The Gambia some varieties developed in Asia for irrigated cultivation also perform well in the uplands, which is due to the plasticity of rice. In the past, ISRA, IRAT and, nowadays, WARDA have developed upland varieties of which many were not adopted by farmers. Very often, projects were funded for periods of 3-4 years, in which potential successful material could be identified on-station, and sometimes also tested on-farm, but no funding was available for the distribution and promotion of these varieties.

In the case of millet, the focus of research institutes like ICRISAT was on early millet only, particularly since the reduction in rainfall in the early 1970s. Formal varieties of early millet, however, are found to yield just as much as farmer varieties in The Gambia. This is common in the whole of West Africa (Matlon, 1985, in Niangado, 1999).

For The Gambia, 3 main causes are found for the limited success of formal varieties:
- development of varieties that are not acceptable to farmers, or do not clearly perform better than farmer varieties
- lack of continuity of variety testing, due to lack of sustained funding
- limited capacities of extension services, constraining the promotion of formal varieties

A fourth (minor) cause is the lack of skills for variety testing (for example, no proper testing of disease resistance).

In the past 10 years, much has been said and done in relation to the first cause, and nowadays breeders have a better understanding of how to develop varieties that meet farmers' requirements. The second, third and fourth cause come down to lack of funding, which implies that if more funding were available, more potential varieties would reach farmers' fields. The WARDA upland PVS trials, which proved very successful in various West African countries, indicate that good and continuous promotion adds significantly to the success of formal varieties.

The strengths of the formal sector are that it can collect and test varieties developed in different countries in the world, and, theoretically, can distribute these varieties among farmers in a country such as The Gambia in an efficient and co-ordinated way.

<u>The place of formal rice varieties in the Gambian farming system</u>

For rice, the formal sector develops varieties that are morphologically very similar. In this study, two ideotypes were identified: one with very short stems and many tillers, and the other with longer stems, few tillers and big panicles (see Chapter 10). Varieties of the same ideotype often have the same panicle morphology. Because of the low distinguishability of these varieties, farmers easily mix up these varieties during harvesting, threshing and storage.

For the functioning of the farmer seed system, varieties need to be morphologically different; otherwise farmers cannot keep them separate from other varieties and exchange them. The variety names farmers use, usually, refer to morphological traits. So, to avoid formal varieties getting mixed-up in farmers' seed systems, formal varieties need to be different from other formal varieties and from farmers' varieties. In Chapter 10 some examples are given of formal varieties that got mixed up in farmers' seed systems. Some of these varieties were genetically very similar, but others were genetically very different.

The place of formal millet varieties in the Gambian farming system

In the case of millet, farmers indicated that it is very difficult to distinguish threshed seed of farmer varieties of early and late millet. This is one of the reasons why it is very important for farmers to save their own seed (see Chapter 4).

Another aspect of a cross-pollinating crop, like millet, is that varieties grown near to each other converge genetically. Theory says that in the case a formal variety and a farmer variety are grown side by side the high yielding ability of the formal variety can decline (although in The Gambia there are no differences in yielding ability between formal and farmer varieties of early millet). So, whereas the genetic make-up of formal rice varieties does not change in farmers' fields, formal millet varieties are subject to such change. From this, it follows that there is need for a greater role for the formal seed sector in cross-pollinating crops than for self-pollinating crops, at least, in so far as one wants to maintain the genetic make-up of the formal varieties. Another option, requiring less involvement of the formal sector, is to improve farmer varieties through introgression with formal varieties (see Vom Brocke *et al.*, 2003).

Strengths and weaknesses of farmer crop development in The Gambia

One of the main strengths of the farmer seed system and crop development is that it is not dependent on outside funding, i.e. it is a robust system. An apparent weakness, as this thesis shows, is that farmer crop development is very much a random process. This may not be as much a drawback as often supposed. Simmonds (1989) has argued that formal crop development may possibly be not much better than random selection. This suggests that the added value may come further on in the breeding process. A particular strength of farmer crop development, in this regard, is that farmers only choose those varieties useful for their purposes and fit best their conditions.

Of rice, a wide range of varieties is developed by farmers, which are morphologically diverse and easy to distinguish. Genetically, these varieties are very similar in some cases, while in other cases, they are very diverse (which seems not much different from formal crop development). New varieties of millet do not develop very easily through farmer crop development. A question is whether to view the randomness of farmer crop development (i.e. farmers do not look at the relatedness of new varieties with already existing varieties and farmers do not implicitly direct their crop development strategies) as a positive or a negative feature. One of the weaknesses of farmer crop development is that new potential varieties can get lost before they are tested, distributed to, and known by other farmers. Another weakness is that the efficiency and speed of farmer-to-farmer exchange of new varieties can vary widely.

Improving the formal breeding sector in The Gambia

Currently, the main activities of the formal sector are the testing and distribution of formal varieties. At the moment, hardly any breeding is done at NARI. As was mentioned above, to improve the formal sector, it is necessary to have better qualified staff for variety testing, improved extension capacity for the distribution of varieties and continuous funding to avoid the relatively long processes of variety testing and distribution faltering before it is complete.

In the initial stages of formal crop development farmer varieties were used as base material. At the moment, however, there is only one-way traffic of information and materials, from research to extension to farmers. Instead, there should be two-way traffic between farmers and research with extension playing a central role, not only in the exchange of information but also in the exchange of varieties. This study has shown that farmers develop new rice varieties in their fields, which represent potentially useful genetic diversity. So far, such varieties have been left aside by the formal sector, because they do not show high yield potential under high fertiliser usage, or because they lodge under such conditions. Such rice varieties, however, do perform very well under low or moderate fertility levels and are thus adapted to current, real-life farming conditions. Of one such rice variety, quite popular among farmers, an NGO brought seed to NARI for testing, but NARI disapproved of it because of its relatively low yield, despite its earliness. As was mentioned by Weltzien *et al.* (1996), breeders should take up more the role of facilitators. For millet, an outbreeder, of which new varieties do not develop quickly in farmers' fields, breeders do not need to tap into farmers resources regularly, but do need to develop varieties that are adapted to farmers' conditions and preferences.

In the 1970s and 1980s, NARI was able to test and distribute rice varieties from all over the world. Since the 1990s, the majority of the varieties come from one institute, WARDA. Chapter 10 showed that the level of genetic diversity represented by formal varieties is related to their diverse institutional origins. To keep future options open, it would be good if linkages with a wider range of research institutes were re-established or improved. A disadvantage of this approach is that the varieties developed at these institutes are often not targeted at Gambian conditions. Since The Gambia forms the northern frontier of non-irrigated rice cultivation in West Africa, the ecological conditions are somewhat different from other rice growing areas in West Africa (e.g. Sierra Leone or Cote d'Ivoire, where rainfall is much higher). This implies that, to develop varieties that fit very well to Gambian conditions, either a breeding program is needed within NARI or a satellite breeding program should be established linked to, for example, WARDA or ISRA. However, this approach may hold a constant tension in keeping the breeding material diverse within a homogenising institutional context. Summarising, to improve the formal sector for rice three approaches are needed: 1) two-way traffic is needed with farmers, 2) NARI needs to re-establish or improve its linkages with other research institutes and 3) a local breeding program is needed.

Because variety development in farmers' fields is less dynamic for millet than for rice, the two-way traffic can be less intensive for millet. The third approach seems most important for millet. NARI has tested several formal early millet varieties, but none of these formal varieties outperforms the farmer varieties. For late millet, no significant breeding was done in West Africa and the late millet varieties from ICRISAT are not adapted to Gambian conditions. It is likely that if breeding is done in the target environment, either through a breeding program in NARI or as a satellite program linked to ICRISAT, higher yielding early and late millet will be developed.

Another aspect that should not be forgotten in breeding programs is that during the third stage (Box 12.1), field conditions should be similar to those of farmers' fields.

Box 12.1 Basic stages of any breeding program

1. goal setting
2. creating of genetic diversity (by crossing)
3. selecting the best materials and develop them into stable lines or populations (for clones genotypic stability is automatically achieved in early stages)
4. testing which materials can be further developed into varieties
5. multiplying and distributing of those varieties

Improving the informal sector

In years with good rainfall, the informal sector is very capable in seed provision, but not in years with low rainfall or other disasters. Often, not all areas of the country are affected by disaster. Improving the informal sector would mean improving seed flow from the unaffected areas to the affected areas. Because such situations occur very irregularly, seed flow can best be organised and regulated by the formal sector, which can act quicker and more organised than the informal sector.

In Chapter 4, it was shown that in one village farmers were able to adjust their variety portfolio to the changed climatic conditions in the 1970s very well, while in another village farmers eventually stopped rice farming because they could not find suitable varieties. These two very different outcomes are due to the randomness of the informal system. Because the informal sector is characterised by randomness, more efficient variety distribution can only be achieved through the coupling with the formal sector.

Since informal crop development is characterised by randomness, and whether farmers develop new varieties is primarily determined by time constraints and environmental constraints, it is difficult to indicate how informal crop development can be improved in itself. One possibility may lay in showing farmers the effects of their activities, which, in turn, may increase awareness of the possibilities of informal crop development. The best opportunities are through improving the linkages with the formal sector, which might be in the form of PVS and PPB.

Participatory Crop Improvement in The Gambia

In the following sections the added value of PVS and PPB within the context of The Gambia are discussed.

PVS in The Gambia

PVS-methodologies can be integrated relatively easily into the 'conventional' system of crop development. Usually, PVS programs involve farmers in the fourth stage (Box 12.1): testing which materials can be distributed as varieties. During stages 4 and 5, farmers' preferences and perceptions of the developed varieties are elicited which can be used in the stage of goal setting for the next breeding round. This means that if farmers only participate in the fourth stage, and breeders listen carefully to the farmers' comments, PVS is a powerful tool to develop varieties that meet farmers' needs. Integrating PVS with conventional breeding should lead to varieties better adapted to farmers needs.

PPB in The Gambia

Compared to PVS, PPB is a long-term process, for which funding and institutional infrastructural stability over a long period of time are essential. Furthermore, not only is good co-ordination needed, but also it is essential that those people who co-ordinate PPB projects and work with or assist farmers have thorough knowledge of genetics and crop development. The current situation at NARI presents capacity constraints[17]. Theoretically, PPB-programs can involve farmers in all stages, but the most pragmatic option would be to involve farmers mostly during stages 3 and 4. Indirectly, this involves farmers also in stage 1 (goal setting).

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[17] For the successful PVS trials on rice, conducted from 1998 to 2000 in The Gambia, the potential materials were developed at institutes outside The Gambia and for such trials thorough knowledge of genetics is less of a requirement.

Box 12.2 F3-populations from WARDA

It is widely accepted now that farmers contribute in a significant way in crop development via Participatory Varietal Selection, which entails that farmers are asked to evaluate a large number of potential new varieties, either on-farm or on-station. Then the question arose whether farmers can participate in earlier stages of crop development. To be able to contribute an answer to this question, 5 bulked F3- populations were received from WARDA, of which the parents were an upland and a lowland variety. The 5 bulked F3-populations were divided into halves and were given to in total 10 farmers in two villages in the season of 2002. All women were very curious about the rice. However, the rains of the season of 2002 were very erratic, particularly at the beginning.

In one village, Janack, two farmers did not sow any rice at all and two farmers did sow in time, but due to erratic rainfall the seed only germinated halfway through the rainy season, and did not mature in time. In the other village, Tujereng, four farmers sowed the seed in time, while two farmers sowed it halfway through the season, when rains became regular. Of the four farmers who did sow it in time, one farmer was able to harvest quite some seed, two farmers could not harvest anything, and in one farmer's field everything was eaten by birds because of labour problems in the compound. In total, one out of 10 farmers was able to harvest some seed and said she would sow it the next year. She said that although the rice did not look impressive it is good to try it again to see how it behaves because the past rainy season was not normal. However, the next season she decided not to sow it.

When the rice was given to the women they were told the rice would show some variation, and they should only harvest those rice plants that performed well. Because the F3-populations were the progeny of a cross between a lowland and an upland variety, the populations can be described as medium in duration and exhibited quite a variation. Most of those plots which did not ripen actually did have a few plants that matured but were not harvested. For a more successful exercise, populations with a shorter duration should be given to the farmers.

This experiment also shows the risks of crop development in areas with unpredictable conditions and would be an argument to say that the first phases of crop development should be conducted under more controllable conditions on-station. This agrees with the schedule for PPB as outlined by Witcombe (2002), who suggests starting on-farm testing only in the F5-stage and later.

Whereas in a formal breeding system, farm management is easy to control, it is harder to control in a collaborative system with farmers. Therefore, to avoid the risk of potential material becoming lost in farmers' fields at the developmental stage, one would need stable environmental conditions (Box 12.2). Given farmers' workloads, particularly those of women, one should be careful to assume that farmers automatically are willing to participate. This indicates that there must be good reasons to start a PPB program.

The standard theory about G × E interactions explains that a variety that is well adapted to very marginal conditions is only adapted to those conditions and does not give high yields under more favourable conditions. The cross-over point tends to be toward the lower end of the environmental range, which means that the varieties that do best under favourable conditions also do best under less favourable but not yet extreme conditions (Hill *et al.*, 1998). This suggests that only under particular, extreme conditions local solutions need to be found. For most crops (except rice in salty or acid areas) in The Gambia, growth conditions are not that extreme that very local solutions need to be sought.

The main advantage of PPB in The Gambia may be that it helps keeping the breeding material diverse within a homogenising context. In the case of millet, PPB may enable develop varieties that can yield higher than the farmer varieties. A question that remains to be answered is whether a PPB methodology or a local programme using 'conventional' breeding would give the best outcome. Following the line of thought of Simmonds (1989), breeder selection is not as efficient as is often assumed. Simmonds (1989) argues that there are still various questions left unanswered about scientific selection methods. It might mean that farmer selection may provide more opportunities for crop development, compared to breeder selection, than is generally assumed.

It is generally agreed that after crossing different genotypes the F2 – F4 generations are expected to show a lot of heterosis, which from the F5 onwards gets fixed. Simmonds (1989) shows that selection should produce off-spring that yield much better than the parents, but offspring usually show yield increases of at best a few percent. One of the reasons is that although yield is the most important selection criterion, the highest yielders are not always the best varieties because they are poor in other characteristics. Simmonds points out that another main cause is that the selection efficiency is too low. In most breeding programs selection starts in the F2 with unreplicated plots, while from the F2 - F4 most of the heterosis is not yet fixed. So, ideally, selection should start at earliest in F4, but because of the large numbers involved this is generally viewed as practically impossible. Witcombe and Virk (2001), instead, suggested using a few crosses which facilitates handling large progenies. This might also facilitate involving farmers in breeding. If selection during F2 – F4 is not very efficient, and also difficult to implement in farmers' fields, an alternative breeding approach may be to sow the progenies of a few crosses in farmers' fields up to the F4 or F5 and then start selection. When the F5 is reached, genotypes are almost fixed and selection very much resembles farmers' traditional way of selecting off-types. Furthermore, it is shown in barley and various other crops that traits like number of seeds per plant increase a lot in the first 4-5 generations, but not that much in the later generations (Allard, 1988). It is also shown that farmers are as capable as breeders to select among stable lines (Ceccarelli *et al.*, 2001; Sperling *et al.*, 1993; Gridley *et al.*, 2002).

The more diverse ecological conditions are, the more separate projects and trials are needed, and the higher the number of farmers under different conditions that should participate. If a PPB-program were to be set-up for crops like millet or sorghum, only a few farmers need to participate to develop varieties that will be acceptable to most Gambian farmers. For rice, more farmers will need to participate because more rice ecologies exist. Also, because rainfall is a more critical and unreliable factor for rice, more trial replications, and thus more farmers, are needed as insurance.

Since millet is an outbreeder, more care should be taken to prevent contamination from surrounding fields than for rice. During the development phase, cross-pollination will not be a big problem in millet, either through the use of borders, or by using isolated areas for PPB experiments. But during dissemination of successful materials to other farmers, and when farmers test it in their fields, it is important that the new materials do not get contaminated too much with the 'old' varieties to avoid the new materials from being altered too quickly. For rice, PPB experiments, from development to dissemination of new varieties, can be set up in the usual rice fields, in between other fields, without problems with cross-pollination.

This means that when up-scaling PPB for millet, the critical phase is the dissemination of the new varieties, when they become contaminated with the old varieties, while the critical phase for rice is the development stage because of unpredictable rainfall and the wide range of ecologies.

12.6 Future developments

As mentioned earlier, with more funding and better training, conventional crop development is likely to be more successful in not-too-extreme areas, such as The Gambia. It is then assumed that breeders are willing to develop and test varieties under farmer conditions in The Gambia and according to farmers' needs. In other words: breeders must be willing to institutionalise PVS methodologies. PPB methodologies, generally, are needed only in breeding programs for extreme areas. Based on the information provided by Allard (1988), Simmonds (1989) and Witcombe and Virk (2001), PPB can also be linked to formal crop development. Above, it was indicated there are some questions about the efficiency of institutional crop development. PPB may provide a different angle enabling us to answer these questions.

Because of different village discourses, involving farmers from various villages in variety development will lead to different varieties, even when using the same base material. Involving farmers in crop development might be another option, in addition to *in-situ* conservation, to maintain genetic diversity. However, it cannot be taken for granted that farmers will automatically be interested to participate. Serious thought needs to be given how to involve farmers without their time involved not being rewarded.

In the future, with the improvement of infrastructure and agriculture, when (as some suppose) the formal sector will have largely replaced the informal sector, farmers will obtain their seed mostly from the formal sector. When that happens, the development of new genetic material in farmers' fields largely comes to an end. Currently, institutional development does not make much use of farmer varieties. Much farmer material stored in genebanks is left unused. This and other studies (Jusu, 1999; Glaszmann, 1987; de Kochko, 1987a; 1987b) show that new genetic diversity continuously develops in farmers' fields. A big question is how important that genetic diversity is (whether we need it in the future, and whether it is useful in formal breeding programs)? This then raises a second question - how important is farmer crop development? Such questions can only be answered through experiments and practice.

The fact that the formal seed sector does not specifically develop late millet and upland rice varieties suited to farmer conditions in The Gambia indicates the need for an assessment of the benefits of farmer crop development. As long as formal crop development excludes particular crop types, farmer crop development remains to play an important role in the development of new better varieties of such crop types, particularly in areas that are prone to disaster and ecological change. From this study, and other studies, it is clear that farmers are very capable in managing seed and varieties. Also, the quality of farmer saved seed is often as good, or better, as that obtained through the formal system. This raises the question whether a better starting point in improving agriculture in low-input marginal areas is to consider how what farmers already do can be supported by the formal system, for example, through base broadening (see Simmonds, 1993).

According to Douglas (1986), each institution, whether it is a group of farmers or a research institute, develops its own culture, traditions, line of thinking and perspective on technology development. The information in Chapter 10 indicated that varieties developed at the same institute are morphologically and genetically more similar to each other than varieties developed at different institutes. This suggests that the more institutes are involved in breeding, the wider a range of varieties will be developed, enabling a wider and better choice, and increasing genetic diversity, at field level, village level or regional level (or at all levels). This implies not only might there be alternative ways of buffering robust farmer seed systems through gene transfer modalities such as base broadening, but that institutional diversity will also be a factor of considerable utility.

These questions also relate to the issues of risk and insurance. Apart from yield improvement, another aspect of breeding is the insurance of future options for crop development. Because different institutes develop different institutional thinking, different breeding programs develop different products and different genetic diversity. Hence, many breeding programs and institutes function as insurance for the future. In case of calamities, they also function as re-insurance: it can happen that war, drought or other calamities affect one institute, but not that all institutes are affected at the same time. The idea will be a well diversified international institutional system aware of and attuned to what farmers (robustly) continue to manage for themselves.

12.7 A final point: crop development for poverty reduction

Food security is an aspect of poverty reduction. But greater food security is not possible through crop development alone. More of a systems approach is needed. In Chapter 3 various constraints, such as weeds, birds and lack of fertiliser were described, which hamper the development of agriculture in The Gambia. The only way that crop development, whether conventional or participatory, can improve agriculture, and hence the livelihood of subsistence farmers, is as part of a farming systems approach to understand and solve or decrease all constraints hampering agricultural progress.

Sometimes, dramatic technology developments (e.g. apomixis) are put forward as 'answers' for the food security of the poor. This thesis, however, suggests that the key issue is a better understanding of the complex processes through which crops are formed, maintained and improved. The problem then is to attune scientific institutions to buffer, support and complement local robust processes, rather than seek their replacement through dramatic bio-engineering development, however much they are tailored to apparent needs. Neither culture (including farming styles) nor crop evolution can so easily be swept aside by the designer or engineer.

Appendix 1 First introductory interviews (rice), 2000

Date:
Name:
Name of husband:
Village:

Questions about rice:

-What varieties do you plant? (what are the names)?

-Where do you plant those varieties?

-Is this a maruo or kamanyango?

-If planted in faro, is there water standing most of the time? (yes, occasionally, no)

-How many years are you growing those varieties? (indicate per variety)

-From whom did you get these varieties? (indicate names per variety)

names varieties	area planted	# years grown	source

-Did you grow any other varieties except the varieties just mentioned?

-If yes, why did you replace them?

-Do you give or sell rice to others?

-Do you receive or buy rice from others?

-If yes, what do you use it for?

-When is seed rice removed from the main harvest? (before, during, after harvest, after threshing, before sowing)

-Do you apply any selection when separating the sowing seed?

-If yes, how do you choose the sowing seed for next season?

-In your field, are there also plants that look different from your varieties?

-Are those common or strange varieties (or both)?

-If you see a strange variety, what do you do with it?

-How do you store your seed?

-Do you store the seed for sowing and consumption at the same place?

-Does it happen that at planting time you don't have any seeds available?

-Do you use any inputs?

-How many years do you cultivate the same field?

Other questions:

-What other crops do you grow?

-Do you have income from other activities?

-For how long have you been living in this village?

-How old are you?

-From which ethnic group/tribe are you?

-How many dimbaayaa's are there in the compound?

-How many sinkiroo are there in this compound?

-How many people live within the compound? (more or less)

Thank you very much. Do you have any questions?

Appendix 2 2002-questionnaire on farmers' seed management and cultivation practices of rice

Date: ____________ Interviewer: ____________________

Respondents profile

Name: ______________________________ Age: ______ Tribe: ____________

Village:______________________________ Nr of years in village: _______

Status in compound: ______________

Name of husband: ______________________

level of education: none primary secondary tertiary informal

Agriculture general

1a) Which crops and trees do you grow? (thick in table below)

1b) Which of those crops and trees do you sell? (thick in table below)

crop	grows	sells	crop	grows	sells	crop	grows	sells
rice			findi			mango		
early millet			watermelon			orange		
late millet			cowpea			banana		
sorghum			sweet potato			cashew		
maize			sesame					
cassava			bamb. groundnut					
groundnut								
other:								

1c) Which of the above is the most important crop to you? ______________

1d) Do you also have income from other activities, apart from agriculture?

no job daily labour shop market other: ___________

1e) Do you own cattle? yes / no If yes, how many? ______

1f) Do you own land? yes / no

Varieties and seed management

2a) Which rice varieties have you grown over the past five years?

2b) In which ecology do you plant those varieties? (for faro, ask whether varieties are direct seeded or transplanted (indicate below)

2001	2000	1999	1998	1997
tandako				
faro, direct seeded				
faro, transplanted				

(Ask the following question only if farmer is growing more than 2 varieties of rice)

2c) For millet, normally one or two varieties are grown, why do you grow many varieties of rice?

____

____

2d) Who are your sources for sowing seed?

family extension co-operation

friends NGO other farmers

2e) How often did you need to borrow/buy sowing seed in the past 5 years? _______

If you needed to borrow/buy seed, what was the reason?

bad harvest seed all eaten storage pest other: _______________

2f) Did you give sowing seed to other people in the past five years? yes / no

(NB: make clear to the farmer you mean sowing seed only: and not consumption seed)

If yes, to people inside or outside the village?

inside village outside village both

if outside village: what's the name of the village:

2g) How is the consumption grain and sowing seed stored? (thick in table below)

	consumption grain	sowing seed
threshed		
not threshed		

Seed selection

3a) When is sowing seed set aside from the main harvest?

before harvesting after harvesting just before sowing

during harvesting after threshing

If you select sowing seed before /during harvesting, from which part of the field do you take the seed?

any part of the field the best part, including border

any part of the field, excluding the border the best part, except the border

3b) Do you perform any selection when setting aside the sowing seed? yes / no

If yes, what characteristics do you look at? _______________________________

Ask the next questions only if farmer is also growing millet:

3c) Are the ways that you select sowing seed for rice and millet different or the same?

same different

If different, can you explain the difference? _______________________________

____

3d) Are the characteristics that you look for in rice and millet varieties the same or different?

same   different

If different, can you explain the difference? ____

____

Crop husbandry

4a) How is the rice field ploughed?   (multiple answer is possible)

tractor   oxen   horse   donkey   by hand

4b) How much seed was set aside as sowing seed last year (# bulubaa, cafoo, containers, etc):

_____

4c) How much seed was really used for sowing last year (# bulubaa, cafoo, containers, etc):

_____

Can you specify the amount of sowing seed used per variety grown in 2001?

variety	amount	variety	amount

4d) How many times is the field weeded?

Tandako: _______

Faro, direct seeded: _______

Faro, transplanted: _______

4e) Who does the weeding? (multiple answer is possible)

men   women   whole family   whole family (only women)

boys   girls   whole family (only men)

4f) Do you have any 'kamanimano' in your field?   yes / no

If yes, do you remove these plants from the field?   yes / no

If yes, when:

during weeding   before harvesting   after harvesting

before flowering   during harvesting

4g) Do you sometimes see 'not-common rice plants' (off-types) in your rice fields? yes / no

If yes, what do you think causes the presence of these off-types? ______________________

____

____

4h) Who does the harvesting? (multiple answer is possible)

men women whole family whole family (only women)

boys girls whole family (only men)

4i) How many people work in the rice field regularly? _______

4j) Do you use inputs? How often do you use these inputs? (If farmer is cultivating both tandako and faro, specify in table below)

	every year		irregular		never	
	tandako	faro	tandako	faro	tandako	faro
chem. Fertiliser						
cow dung						
chem. insecticide						
chem. herbicides						
Other:						

Cooking

5a) How often per week do you cook rice?

less than once a week

once - twice a week

three - four times per week (every other day)

6 - 7 times per week (almost every day)

5b) How often per week do you cook millet?

less than once a week

once - twice a week

three - four times per week (every other day)

6 - 7 times per week (almost every day)

Thanks for your co-operation!!!!!!!

Appendix 3 Farmers arguments why more varieties of rice are grown than of millet

Answers of men and women to the question why men only grow 1 or 2 varieties of millet and women often grow more than 2 varieties of rice (data from 2002-questionnaire).

	men	women
total number of respondents (N)	155	134
no answer	27	35
answer	128	99
no idea	24	6
God	7	5
millet is more resistant to drought than rice	12	30
millet is better adapted to the conditions	9	
millet resists birds, unlike rice	2	
rice is grown in many ecologies, while millet is grown in only one	2	8
for rice, long and short duration varieties are used, unlike for millet	1	8
rice varieties have different characteristics		10
many rice varieties are used to reduce labour constraints		10
many rice varieties are used to maximise yield		3
for millet you need varieties that resist birds	33	
not possible to grow other varieties here	4	
soil is unfertile	4	
because of limited labour force	3	
millet is not easy to cultivate	2	
more rice varieties exist than millet	20	5
knows many millet varieties	2	
to look for best varieties		8
extension gives them seed		2
many varieties come out from rice		1
rice varieties are given names, millet is millet		1
because women look for different varieties in different villages	1	1
many people cultivate rice and few cultivate millet	1	1
they grow more rice than millet and depend more on rice	1	

Appendix 4 Yields of various rice varieties

Average yields (in kg / ha) of 10 rice varieties over two years and the two years combined.

variety	Status [1]	2001	2002	average over both years	
Binta Sambou	FV	947	1089	1032	a
Moti	FV	648	1285	1030	a
Kari Saba	FV	899	1104	1001	a
Terfatch	MV	1019	893	943	a
Barafita Koyo	FV	1010	800	884	ab
CCA	MV	625	948	819	ab
Bendou	FV	978	700	811	ab
Teiba	US	981	652	784	ab
Mani Wulendingo	FV	642	848	745	ab
Kukone	US	735	378	557	b
Average		837	870	855	

[1] FV = Farmer variety, MV = Formal variety, US = Unclear Status

Appendix 5 Formal rice varieties officially released by NARI

This list is based on interviews with various researchers from NARI and STU

variety	introduction & origin	areas distributed	characteristics	remarks
Typical upland, also grown under irrigation and in lowlands				
Peking	late 1960s (most likely from Brazil)	throughout the whole country, mostly in areas not dependent on rainfall	early, shatters, short	1) 2)
Se 302 G (or IRAT 11)	1970s ISRA	not in CRD, maybe in LRD and/or WD	low yield, short, early	whipped out by blast 3)
WAB 56-50	late 1990s WARDA			released but not yet multiplied by STU
WAB 99-50	late 1990s WARDA			released but not yet multiplied by STU
Most suited for lowland where water is standing, also widely grown in uplands and under irrigation				
CCA	Taiwan	throughout the country, especially in WD	quite early (not as early as Parasana), high yield	high demand for CCA
Parasana	1987/88 India	mostly in the eastern part of the country, in areas not dependent on rainfall, LRD and CRD	early, tall, good palatability, susceptible to blast	1) 2) 4) 5)
DJ 11-509	1980s ISRA		medium duration	no seed available anymore 4)
Mostly grown in lowland, not in typical upland (only do well in uplands with good water retention capacity)				
DJ 12-519	1980s ISRA		similar to DJ 11-509	
Rasi	1987/88 India	NBD, URD, Foni	medium duration	
Other old formal varieties, of which no information is available on diffusion				
IRAT 10	IRAT	suitable for Senegal		6)
IRAT 110	IRAT	suitable for The Gambia		6)
IRAT 112	IRAT	suitable for The Gambia		6)
I Kong Pao	Djibelor	suitable for irrigated areas		7)
Se 314 G	Djibelor	never released		
Se 319 G (or IRAT 12)	Djibelor	not officially released	similar to Se 302G but yields less	

1) Under irrigation it yields less than other varieties because of its earliness; farmers only grow it if market is assured.
2) Parasana replaced Peking because of its higher yield, but farmers started asking for Peking again.
3) It is out of the formal system.
4) Under upland cultivation it needs rain every 2-3 days, particularly the milky stage is critical.
5) It is susceptible to blast (In general blast [leaf blight] is more common in the lowlands than in the uplands)
6) Recommended upland rice varieties identified in WARDA trials (Gupta and Tools, 1986)
7) FAO-website: www.fao.org/waicent/faoinfo/agricult/agp/agpc/doc/riceinfo/wapvdef.htm

Appendix 6 Rice varieties shared among the sampled villages

Number of rice samples per variety per village (data from 2002-questionnaire combined with data from 2000-interviews)

Variety	Tujereng	Kartung	Kitty	Faraba	Janack	Batabut	Sangajor	Jiroff	Massembe	Sanending	# samples
Akacha			2								2
Akacha 2		5									5
Alima Mano									2		2
Atu Mano							1				1
Badjie Mano							1				1
Balinding Mano	1										1
Bamba Mano									4		4
Banja						2					2
Banjul Mano								3		6	9
Barafita Koyo	1		2	2	1		1				7
Barafita		1	1			1					3
Baras	1		1				1				3
Baraso			1	7							8
Barass	1		3								4
Barass 2	1	1	1	7							10
Barass 3						1					1
Basett				1		6					7
Basso Mano									6		6
Bendou	2										2
Bendou 2			1								1
Binta Sambou	6		3	1							10
Bintou Mano			1								1
Bonti	1				1						2
Burukusndingo			1	1							2
Butter			1								1
Butter Mano		2									2
Butung			2								2
Chinese				1							1
Dinding Mano								3	1		4
Fatou Demba Mano	1										1
Ferroso		2									2
Foni Mano	1		1								2
Ginubor						1					1

Variety	Tujereng	Kartung	Kitty	Faraba	Janack	Batabut	Sangajor	Jiroff	Massembe	Sanending	# samples
Hombo Wulengo	2										2
Jaafa				1							1
Jamisa		6	3						2		11
Jorang Mano								4			4
Kadi Dabo					1						1
Kadi Dabo 2							1				1
Kafuta										6	6
Kamaso			1								1
Kamasori			2	1							3
Kamasorr				1							1
Kari Saba	11		2	3	2						18
Kossa Mani Koyo									2		2
Kossa Mano									3		3
Koya Mano								5			5
Kubomp				1							1
Kukone					1						1
Kukur	2										2
Kumoi			4	2							6
Kurukuti					1						1
Loftin				1							1
Mani Mesengo	2										2
Mani Suntungo			1	3	1						5
Mani Wulendingo	3		1		1						5
Mani Tima					1						1
Mani Koyo	2									1	3
Mani Koyo 1								1			1
Mani Koyo 2	1										1
Masarinding Mano	1										1
Mbabinke			1								1
Mbambase		2									2
Moti					4						4
Muso Noringo	1										1
Namo Mano									1		1
Nyanya	1										1
Nyiba Mano								1			1
Nyiba Mano 2								4			4

Variety	Tujereng	Kartung	Kitty	Faraba	Janack	Batabut	Sangajor	Jiroff	Massembe	Sanending	# samples
Nyiokoro								1			1
Nyomo								3			3
Peking 31?			1				1				2
Peking 32?				1	2						3
Peking 34?				1			2				3
Peking					1						1
Peking (				1							1
Peking 29?					1						1
Peking?			1	3	2		2				8
Saidy Kunda Mano			1								1
Saidy Mano			1								1
Sainy Kolly	1										1
Sammeh									1		1
Sammere								2			2
Sankanyi								1			1
Sarrakunda Mano									6		6
Sarrakunda Mano 2									1		1
Sefa Fingo	2										2
Sefa Koyo	4										4
Sefa Nunfingo	1										1
Serebondi										2	2
Sonna Mano	2										2
Teiba				5							5
Tensi					1						1
Terfatch			4	5	4		3				16
Tijan							4				4
Tombom Mano					1						1
Tombom Mano 2				1							1
Tujering			1								1
W/bank			1								1
W/bank 2										1	1
Wesiwes					2						2
Yayego				1							1
# varieties	25	7	29	23	18	5	10	11	11	5	
# samples	52	19	46	51	28	11	17	28	29	16	

Appendix 7 Off-types found in rice samples, per variety and village

Total quantity (in%) and number of off-types found in samples of rice varieties from the villages Tujereng, Kitti, Faraba and Janack; each sample consisted of about 300 panicles harvested by the woman from whom the sample was obtained. Variety names of samples are shown in the second column and the names of the off-types found in these samples are shown in the header row. The scores of off-types per variety are shown in bold (based on the samples collected with the 2000-interviews).

village [1]	variety name	off-types / sample (in %)	# distinct off-types/ sample	Kari Saba	Binta Sambou	Tombon Mano	Bendou	Peking	Sefa Koyo	Sonna Mano	Kumoi	Barafita Koyo	Terfatch	Akacha	Mani Mesengo	Baraso	Tensi	Big Sonna	Mani Suntung	strange off-type	Mani ba
T	Kari Saba	16-30	6		1	1	1		1					1							
T	Kari Saba	16-30	2		1				1												
T	Kari Saba	< 3	2		1							1									
T	Kari Saba	8-15	3		1			1													1
T	Kari Saba	4-7	1		1																
T	Kari Saba	< 3	4		1	1			1			1									
T	Kari Saba	8-15	4		1			1		1											
T	Kari Saba	16-30	1		1																
T	Kari Saba	16-30	3		1				1						1						
T	Kari Saba	>30	2		1				1												
T	Kari Saba	4-7	2	1																	1
K	Kari Saba	16-30	6			1					1	1									1
K	Kari Saba	16-30	8		1		1	1				1					1		1		1
F	Kari Saba	< 3	2		1			1													
F	Kari Saba	< 3	3		1			1								1					
J	Kari Saba	8-15	4	1		1		1			1										
	Variety total			**2**	**13**	**4**	**2**	**6**	**5**	**1**	**2**	**4**	**0**	**1**	**1**	**1**	**1**	**0**	**1**	**0**	**4**
K	Peking?	>30	8	1						1	1		1	1						1	1
K	Peking?	< 3	3							1						1					
F	Peking?	4-7	1																		
F	Peking?	< 3	5	1			1				1						1				
F	Peking?	4-7	5	1							1										1
J	Peking?	< 3	2	1									1								
J	Peking?	4-7	2							1			1								
J	Peking?	< 3	2	1																	
J	Peking?	< 3	3	1		1							1								
J	Peking?	4-7	4	1		1	1						1								
	Variety total			**7**	**0**	**2**	**2**	**0**	**0**	**3**	**3**	**0**	**4**	**0**	**0**	**1**	**1**	**0**	**0**	**1**	**2**

village [1]	variety name	off-types / sample (in %)	# distinct off-types/ sample	Kari Saba	Binta Sambou	Tombon Mano	Bendou	Peking	Sefa Koyo	Sonna Mano	Kumoi	Barafita Koyo	Terfatch	Akacha	Mani Mesengo	Baraso	Tensi	big sonna	Mani Suntung	strange off-type	Mani ba
T	Barafita Koyo	4-7	7	1		1		1					1	1							1
T	Barafita Koyo	4-7	9	1	1					1			1		1						1
K	Barafita Koyo	8-15	7	1		1		1		1	1					1					
F	Barafita Koyo	4-7	5	1				1								1					1
F	Barafita Koyo	>30	4	1		1	1				1										
	Variety total			**5**	**1**	**3**	**1**	**3**	**0**	**2**	**2**	**0**	**2**	**1**	**1**	**2**	**0**	**0**	**0**	**0**	**3**
T	Binta Sambou	16-30	8	1		1	1		1			1						1		1	
T	Binta Sambou	4-7	3	1		1			1												
T	Binta Sambou	< 3	2	1					1												
T	Binta Sambou	< 3	1						1												
T	Binta Sambou	16-30	3	1		1			1												
T	Binta Sambou	< 3	1	1																	
K	Binta Sambou	4-7	4	1			1	1						1							
K	Binta Sambou	< 3	6	1		1		1					1							1	1
F	Binta Sambou	4-7	4	1				1				1							1		
	Variety total			**8**	**0**	**4**	**2**	**3**	**5**	**0**	**0**	**2**	**1**	**1**	**0**	**0**	**0**	**1**	**1**	**2**	**1**
K	Baraso	16-30	8	1			1			1	1										1
F	Baraso	4-7	4	1				1		1									1		
F	Baraso	4-7	6			1	1	1					1								
F	Baraso	16-30	3	1				1													1
	Variety total			**3**	**0**	**1**	**2**	**3**	**0**	**2**	**1**	**0**	**1**	**0**	**0**	**0**	**0**	**0**	**1**	**0**	**2**
K	Kumoi	4-7	4	1	1	1		1													
K	Kumoi	< 3	5	1	1									1	1						1
K	Kumoi	< 3	1																		
F	Kumoi	< 3	2				1										1				
	Variety total			**2**	**2**	**1**	**1**	**1**	**0**	**0**	**0**	**0**	**0**	**1**	**1**	**0**	**1**	**0**	**0**	**0**	**1**
T	Hombo Wulengo	>30	11	1	1	1	1		1	1		1		1	1					2	
T	Hombo Wulengo	< 3	4	1	1		1													1	
T	Hombo Wulengo	>30	7	1	1		1		1		1							1		1	
T	Hombo Wulengo	4-7	4	1	1	1	1														
	Variety total			**4**	**4**	**2**	**4**	**0**	**2**	**1**	**1**	**1**	**0**	**1**	**1**	**0**	**0**	**1**	**0**	**4**	**0**
T	Sefa Koyo	>30	6	1	1		1								1		1	1			
T	Sefa Koyo	16-30	4		1	1		1										1			
T	Sefa Koyo	16-30	3		1		1														
T	Sefa Koyo	16-30	4		1		1											1	1		
	Variety total			**1**	**4**	**1**	**3**	**1**	**0**	**0**	**0**	**0**	**0**	**0**	**1**	**0**	**1**	**3**	**1**	**0**	**0**

[1] T= Tujereng, K = Kitti, F = Faraba and J = Janack

Appendix 8 Frequencies of off-types in rice varieties

Frequencies that common, other and strange rice varieties were found as off-type in rice varieties, expressed as ratio and as percentage of the number of samples representing other varieties per village (based on the samples collected with the 2000-interviews).

	Tujereng		Kitti		Faraba		Kitti		Total	
off-types /sample	#	%	#	%	#	%	#	%	#	%
Total # samples	44	100	12	100	16	100	18	100	90	100
common varieties										
Kari Saba	24/33	73	7/10	70	8/14	57	8/17	47	47/74	64
Binta Sambou	32/38	84	3/10	30	2/15	13	0/18	0	37/81	46
Peking	7/44	16	5/10	50	9/13	69	6/13	46	27/80	34
Tombom	13/44	30	5/12	42	2/16	13	5/17	29	25/89	28
Bendou	13/43	30	3/12	25	4/16	25	4/18	22	24/89	27
Sefa Koyo	15/39	38	0/12	0	0/16	0	1/18	6	16/85	19
Kumoi	4/44	9	4/9	44	3/15	20	4/16	25	15/84	18
Sonna Mano	5/41	12	4/12	33	1/16	6	1/18	6	11/87	13
Barafita Koyo	9/42	21	2/11	18	1/14	7	0/18	0	12/85	14
Terfatch	3/44	7	2/12	17	1/16	6	4/16	25	10/88	11
Akacha	4/44	9	3/11	27	0/16	0	1/18	6	8/89	9
Bonti	1/43	2	2/12	17	0/16	0	5/17	29	8/88	9
Baraso	0/44	0	2/11	18	3/12	25	2/18	11	7/85	8
Hombo Wulengo	5/40	13	0/12	0	0/16	0	1/18	6	6/86	7
Mani Mesengo	5/41	12	1/12	8	0/16	0	0/18	0	6/87	7
Tensi	1/44	2	1/12	8	2/16	13	1/17	6	5/89	6
Mani Wulendingo	3/44	7	1/12	8	0/16	0	0/17	0	4/89	4
Kukur	3/42	7	0/12	0	0/16	0	0/18	0	3/88	3
Teiba	0/44	0	1/12	8	2/12	17	0/18	0	3/86	3
Sefa Nunfingo	1/43	2	1/12	8	0/16	0	0/18	0	2/89	2
Sainy Kolly	1/43	2	1/12	8	0/16	0	0/18	0	2/89	2
Chinese Red	0/44	0	0/12	0	1/15	7	0/18	0	1/89	1
Kadi Dabo	0/44	0	1/12	8	0/16	0	0/17	0	1/89	1
Kukone	0/44	0	1/12	8	0/16	0	0/17	0	1/89	1
Mani Tima	0/44	0	1/12	8	0/16	0	0/17	0	1/89	1
other varieties										
Parasana	1/44	2	1/12	8	1/16	6	0/18	0	3/90	3
other MV's	6/44	14	4/12	33	3/16	19	1/18	6	14/90	16
Banjul Mano	0/44	0	1/12	8	1/16	6	0/18	0	2/90	2
Mani Mesendingo	1/44	5	1/12	8	0/16	0	0/18	0	2/90	2
Dark Sefa Fingo	1/44	2	0/12	0	0/16	0	0/18	0	1/90	1
Mani Ba (*O. glaberrima*)	5/44	11	6/12	50	4/16	25	0/18	0	15/90	17
strange off-types[1)]										
Big Sonna	6/44	14	0/12	0	0/16	0	1/18	6	7/90	8
Short Bendou	1/44	2	1/12	8	1/16	6	2/18	11	5/90	6
Bar Koyo with awn	1/44	2	0/12	0	2/16	13	1/18	6	4/90	4
Bendou with bristle	1/44	2	0/12	0	0/16	0	0/18	0	1/90	1
Dark Kari Saba	0/44	0	1/12	8	0/16	0	0/18	0	1/90	1
Fat Kari Saba	0/44	0	0/12	0	0/16	0	1/18	6	1/90	1
Red Tensi	1/44	2	0/12	0	0/16	0	0/18	0	1/90	1
Red Sonna Mano	2/44	5	0/12	0	0/16	0	0/18	0	2/90	2
Yellow Big Sonna	1/44	2	0/12	0	0/16	0	0/18	0	1/90	1
Mani Koyo with purple bristle	1/44	2	0/12	0	0/16	0	0/18	0	1/90	1

1) The names indicate a resemblance of the off-types with these varieties.

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Summary

In many tropical countries we can distinguish two seed systems: a formal seed system (comprising breeding companies and national institutes) and an informal seed system, often called farmer seed system (comprising of all farmer activities related to the transfer of seeds). These two systems are intertwined in various degrees for different crops and different regions. Related to these two seed systems are formal and informal crop development systems. In recent years, it is suggested to link these two systems in a more structural way, for example, through Participatory Variety Selection and Participatory Plant Breeding. Various research projects have shown that the integration of these two systems is feasible and provide various advantages compared to formal crop development, such as varieties that better fit farmer' preferences and are better adapted to their conditions, a higher adoption rate of varieties, enhancement of biodiversity and germplasm conservation. It is often suggested that farmer varieties are well adapted to local conditions and that farmers maintain high levels of diversity in their fields, enabling conditions for the creation of new genetic diversity and new varieties. However, how exactly farmers manage such processes, or whether they actually manage these processes at all is not much studied. With better information it will be possible to identify opportunities to maintain and enhance farmer selection practices, and to prevent elimination of local processes of value in maintaining genetic diversity. Hence, the objective of this study was to get a better understanding of local gene flow and its effects on crop genetic diversity (i.e. availability, genetic make-up and diversity of varieties) and as such on the farming system as a whole, and whether these effects are related to or influenced by breeding system, gender, farmer selection, or possibly other agricultural practices, socio-economic factors or cultural understandings, consciously or tacitly.

The three main research questions that follow from this objective were:

1. How is gene flow managed by farmers and which factors play a crucial role?
2. What is the impact of gene flow on the adaptability and resilience of the farming system?
3. Based on the answers to questions 1 and 2, what suggestions can be made to integrate formal and informal crop improvement?

To answer these questions, the following model of gene flow is used:

Gene flow = (seed flow + pollen flow) * selection pressure

To achieve a better understanding how the various factors related to seed flow, pollen flow and selection pressure interact an interdisciplinary approach is used combining natural and social science. A comparative approach is chosen focusing on two key-variables: crop breeding system and gender. In The Gambia millet (an outbreeding crop) is grown by men and rice (an inbreeding crop) grown by women. During the fieldwork, farmer cultivation practices, seed selection and use and management of varieties are compared between millet and rice and between men and women. In the analyses, quantitative and qualitative plant data and socio-economic data are integrated. Chapters 2 to 9 described the various aspects of the model above. In chapter 12, the concluding chapter, these aspects are brought together and the short formula on gene flow (presented in Chapter 1) further elaborated. With this information, and information from Chapters 10 and 11, the second research question is answered. Finally, this information is used to illuminate the third question through some suggestions on how formal and informal crop improvement might be better integrated.

Selection pressures

Chapter 4 elaborated on selection pressures within varieties, while Chapter 5 dealt with selection between varieties. From data in Chapter 4 it became clear that the differences between seed lots of the same varieties are small for millet, and almost non existent for rice. In the case of rice, selection within varieties is practically impossible because of the large numbers of panicles needed for seed, and, secondly, because rice is an inbreeding crop with little genetic variation within populations. For millet, selection within varieties is possible, but probably has very little effect in terms of improvement because of the varying conditions from year to year and, secondly, because of the rather large numbers of spikes (up to 1000) selected for seed. Furthermore, because environmental conditions do not differ much between different areas in The Gambia, natural selection pressures only have small divergent effects on millet populations. As indicated in Chapter 5, there are many more rice varieties than millet varieties. Women also grow more varieties of rice than men do of millet. These differences can be explained by difference in breeding system (see under pollen flow), ecological complexity and number of variety selection criteria. Another factor seems to be that whereas women mainly grow rice during the rainy season, men grow a range of crops because of which they only grow, on average, one millet variety. The difference in varietal diversity seems largely unrelated to gender-based skill factors (under this assumption it being argued that women are better in variety management as a result of which more rice varieties exist than millet varieties). In Chapter 9 it is argued that these differences are the result of complex social relationships. From the grouping exercise in Chapter 9 it also can be concluded that men and women manage varieties similarly.

Seed flow

Farmers clearly attempt to manage seed flow. This was the topic addressed in Chapter 6. The chapter shows that various factors influence and determine seed flow. The main factors are seed loss, need for new varieties (related to change in environmental, socio-economic and cultural conditions) and the existence (or absence) of channels through which seed can flow. In a traditional farming system these channels are kinship lines, friendships, trade relations and markets. Nowadays, the formal seed sector is an extra channel, although through this channel seed flows only in a one-way direction (from the formal sector to farmers). Because about one third of the women marry outside their village, these links to their family in other villages is an important channel for rice seed flow between villages, whereas in the case of millet, cultivated by men, there is very little seed flow between villages. Another explanation for the limited millet seed flow is that there are very few millet varieties compared to rice varieties and thus there is less need for seed exchange between villages. For rice, most seed flow between villages is meant for the testing of new varieties. Most rice seed flow within villages is geared towards replacing lost seed stocks. Variety naming provides information about the level of variety flows. In those villages where varieties have common names there may be less seed flow than in villages where varieties lack common names. Variety names also give insights on the time a variety is in a village and whether it is used widely. Differences in rice and millet naming are related to the fact that millet varieties are less often replaced than rice varieties.

The more varieties that exist, the more seed flow and more variation in seed flow between villages. The factors influencing variety use and the number of varieties that exist for a particular crop are: extremity and unpredictability of environmental conditions, diversity of environmental conditions, total number of crops grown by farmer, number of uses of the crop, importance of the crop, crop breeding system, ease of reproduction, labour organisation and market organisation. Various socio-economic and cultural factors influence seed flow, with both positive and negative effects on genetic diversity, depending on the context. An example is the impact of increased rice imports and the increased perception that *O. glaberrima* is difficult to pound on the reduced seed flow of *O. glaberrima*, as explained in Chapter 5.

Pollen flow

Compared to seed flow, pollen flow is not consciously managed by farmers. Chapter 7 shows that pollen flow is very different for rice and millet because of various factors. The most important factor is the rate of outbreeding, millet being an outbreeding crop and rice an inbreeding crop. For pollen flow to result in the development of new genotypes, the level of pollen flow should not be too high. Distinct, stable genotypes develop more easily in crops with a low cross-pollination rate, like rice. Hence, it is also easier for farmers to select off-types in strong inbreeding crops, and develop them into new varieties, than in strongly outbreeding crops. Other factors determining the chances of the development of new stable genotypes are the distances between fields, the time of flowering, the number of varieties in different fields and the number of mixed-in varieties within fields. Farmers do not mind mixed-in varieties in their seed as they consider it insurance. Because of all these factors, chances of cross-pollination between rice varieties are much higher within fields than between fields. Since within a village almost all farmers grow the same variety of millet chances of pollen flow between millet varieties are very low.

Chapter 8 shows that, compared to pollen flow between varieties, pollen flow between cultivated plants and wild relatives occurs less frequently (more for rice than for millet) because wild relatives are only found in low numbers in cultivated fields and they often flower earlier than the cultivated plants. Furthermore, interspecific pollen flow is less effective because of genetic incompatibility (more for rice than for millet). Farmers manage pollen flow between cultivated crops and wild relatives in an indirect way. Farmers do not care much about wild relatives when they are present in the field in very low numbers, indirectly allowing a little pollen flow. When wild relatives are found in the fields in higher numbers and threaten to outcompete the cultivated crop, farmers weed the wild relatives, reducing pollen flow.

In general, farmers think off-types are caused by God and they do not have a clear understanding of what exactly causes change in rice and millet. Although men and women have a similar understanding on the development of strange off-types in millet and rice, men have never tried to test strange millet off-types, while women sometimes test and develop strange rice off-types into new varieties. As mentioned above, new stable, distinct off-types develop more easily in rice than in millet. Distinctness of off-types is a requirement for farmers to notice them. The harvesting process enables observations of strange off-types in rice more readily than in millet. Additionally, this study found evidence that it is an aspect of male identity not to test any strange off-types. Men often know how to differentiate varieties, but seemingly this is not knowledge that is important to their self image and to their image within the community.

Impact of gene flow on adaptability and resilience

The second main research question was whether gene flow plays a role in keeping farming systems adaptable and resilient. In Chapter 10 it was concluded that processes in relation to genetic diversity differ between rice and millet. In the case of rice, pollen flow between varieties and farmer off-type-selection have important roles in the development of new varieties. Moreover, for rice, seed exchange between communities is crucial to maintain genetic diversity at village level and regional level, whereas it is less important for millet. In millet it is primarily pollen flow within varieties and seed selection through which genetic diversity is maintained. It is likely that genetic diversity for rice fluctuates more over time and space than for millet. For rice, the effect of pollen flow and seed flow on genetic diversity shows in the development of new varieties, whereas for millet, seed and pollen flow lead to the maintenance, or in some cases an increase, of genetic diversity at population level.

In Chapter 11 it was elaborated that adaptability (and resilience) can be achieved through genetic diversity and plasticity. Chapter 11 elaborated further on the impact of selection on local adaptation. It shows that millet varieties are not narrowly adapted and that variety choice seems more related to cultural preferences than to local adaptation. Although no data are available, it seems that rice varieties are also quite widely adaptable. For rice, another factor that seems to influence variety choice is the time of introduction of varieties in a village and the range of suitable varieties in that village.

It is probable that at farming system level pollen flow plays a limited role in keeping populations adaptable to rapid environmental changes. This does not mean that the process of adaptation through genetic evolution at field level should be ignored, but that it is too slow a process, compared to the decision making process of farmers who can decide in a few years (sometimes in only one year) to change varieties.

Importance of gene flow

In Chapter 12 the implications of these findings for the importance of gene flow are discussed. Under slowly changing conditions, a high cross-pollination rate contributes to adaptation at field level, which then in turn contributes to adaptation at farming system level. Under fast changing conditions (whether ecological or socio-economic), seed flows (exchange of varieties) are essential to maintain adaptation at farming system level. A low cross-pollination rate also contributes to the adaptability of farming systems through the development of new varieties. Hence, it can be argued that for late millet the process of adaptation is more gradual, while for rice it is more of a stop-and-go process. Whereas late millet populations slowly adapt to the changing climatic conditions in The Gambia, rice varieties tend toward replacement when the 'older' ones do not fit the conditions anymore.

Integrating farmer breeding with scientific breeding

Finally, in chapter 12 some suggestions are given how to integrate farmer and formal breeding in the context of The Gambia. There is scope to improve the formal breeding system in itself, particularly by improving funding conditions and the capacity of NARI. Important is also to stimulate two-way traffic of information and seed materials between researchers and farmers, and local testing of materials. As farmer breeding is very much a random process, which is also one of its strengths, it is difficult to improve it. There is more scope in improving farmer breeding by linking it to the formal system. One way to link farmer and formal breeding is through PVS methodologies which can be easily integrated into the 'conventional system of crop improvement'. If formal breeding is improved following the above suggestions, PPB methodologies do not have any apparent advantages in the context of The Gambia, but may be used to reflect how conventional breeding methods can be improved. In the last section it is emphasised that as long as formal crop development excludes particular crop types, farmer crop development remains to play an important role, particularly in risk-prone environments. A last remark is that crop development can only improve agriculture as part of a farming systems approach understanding the complex processes through which crops are formed, maintained and improved.

Samenvatting

In veel tropische landen kunnen we twee zaaizaadsystemen onderscheiden: een formeel systeem (bestaande uit veredelingsbedrijven en nationale onderzoeksinstituten) en een informeel systeem, wat vaak een boerenzaaizaad systeem genoemd wordt (bestaande uit alle boerenactiviteiten die te maken hebben met de uitwisseling van zaad). Deze twee systemen zijn vaak verstrengeld in meer of mindere mate voor verschillende gewassen en regio's. Gerelateerd aan deze twee systemen zijn een formeel en informeel gewasontwikkelingssysteem. In de afgelopen paar jaar is het idee geopperd om deze twee systemen in een meer gestructureerde manier aan elkaar te koppelen, bijvoorbeeld door middel van Participatieve Ras Selectie en Participatieve Plantenveredeling. Verscheidene onderzoeksprojecten hebben aangetoond dat de integratie van deze twee systemen mogelijk is en dat dit verschillend voordelen te bieden heeft, zoals rassen die beter voldoen aan de voorkeuren van boeren en beter aangepast zijn aan lokale omstandigheden, een hoger gebruik door boeren, en verbetering van biodiversiteit en behoud van genetische bronnen. Het is vaak gesuggereerd dat landrassen goed aangepast zijn aan lokale omstandigheden en dat boeren veel gewasdiversiteit in hun velden handhaven. Daarmee creëren ze gunstige omstandigheden voor de ontwikkeling van nieuwe genetische diversiteit en nieuwe rassen. Echter, er zijn geen studies gedaan naar hoe boeren precies dergelijke processen beheren, en of ze eigenlijk wel zulke processen beheren. Met meer en duidelijkere informatie kunnen mogelijkheden om boerenselectie te behouden en te stimuleren worden geïdentificeerd. Of kan worden voorkomen dat lokale processen die gunstig zijn voor het behouden van genetische diversiteit gestopt worden. Hieruit volgt het doel van deze studie: Een beter begrip te krijgen van lokale genenstromen (gene flow) en haar effecten op genetische diversiteit van gewassen, en als zodanig op het landbouwsysteem in zijn geheel, en of deze effecten zijn gerelateerd aan bestuivingsysteem, sekse, boerenselectie, of mogelijk andere teeltmethoden, sociaal-economische of culturele factoren.

Drie centrale onderzoeksvragen zijn gerelateerd aan dit doel:
1. Hoe worden genenstromen beheerd door boeren, en welke factoren spelen daarin een cruciale rol?
2. Wat is het effect van genenstromen op het aanpassingsvermogen en veerkracht van een landbouwsysteem?
3. Welke suggesties zijn mogelijk om formele en informele gewasverbetering te integreren gebaseerd op de antwoorden op vragen 1 en 2?

Om deze antwoorden te kunnen beantwoorden, is het volgende model voor genenstromen gebruikt:

Genenstromen = (zaadstromen + pollenstromen) * selectiedruk

Om beter te begrijpen hoe de factoren die gerelateerd zijn aan zaadstromen, pollenstromen en selectiedruk elkaar beïnvloeden, is een interdisciplinaire beta-gamma benadering gebruikt. De belangrijkste twee variabelen waar het onderzoek zich op richt zijn bestuivingmechanisme en sekse. In Gambia wordt gierst (een kruisbestuiver) geteeld door mannen en rijst (een zelfbestuiver) door vrouwen. Tijdens het veldwerk zijn de teeltmethoden, zaaizaadselectie en het gebruik en management van rassen vergeleken tussen gierst en rijst, en tussen mannen en vrouwen. In de analyses zijn kwantitatieve en kwalitatieve gewasgegevens en sociaal-economische gegevens geïntegreerd. Hoofdstukken 2 t/m 9 beschrijven verscheidene aspecten van het model. Met de verkregen informatie was het mogelijk om bovenstaand model (zie

hoofdstuk 1) verder uit te breiden (zie hoofdstuk 12). Met deze informatie, en de informatie uit hoofdstukken 10 en 11 kan de tweede onderzoeksvraag beantwoord worden. Uiteindelijk is deze informatie gebruikt om de derde onderzoeksvraag te beantwoorden hoe de formele en informele gewasverbetering beter geïntegreerd kunnen worden.

Selectiedruk

Hoofdstuk 4 beschreef selectiedruk binnen rassen, terwijl hoofdstuk 5 selectie tussen rassen beschreef. Van de gegevens in hoofdstuk 4 werd duidelijk dat de verschillen tussen zaadmonsters van het zelfde ras klein zijn voor gierst, en er bijna geen verschillen in het geval van rijst. Voor rijst is selectie binnen rassen ook praktisch onmogelijk vanwege de grote aantallen pluimen (tot 20.000) die nodig zijn voor zaaizaad, en, ten tweede, omdat rijst een zelfbestuiver is met weinig genetische diversiteit binnen rassen. Voor gierst is selectie binnen rassen wel mogelijk, maar heeft waarschijnlijk weinig effect vanwege de variabele omstandigheden van jaar tot jaar, en ten tweede, vanwege de vrij grote aantallen aren (tot 1000) die nodig zijn voor zaad. Bovendien kan natuurlijke selectiedruk weinig divergerend effect hebben op gierstpopulaties vanwege de kleine verschillen tussen gebieden in Gambia. In hoofdstuk 5 is aangegeven dat er veel meer rijstrassen bestaan dan gierstrassen. Bovendien gebruiken vrouwen meer rijstrassen dan dat mannen gierstrassen gebruiken. Deze verschillen zijn te verklaren door verschillen in bestuivingmechanisme, ecologische complexiteit, en het aantal selectiecriteria voor rassen. Een ander factor is waarschijnlijk dat terwijl vrouwen hoofdzakelijk rijst verbouwen in het regenseizoen, mannen een verscheidenheid aan gewassen telen, wat er aan bijdraagt dat ze slechts een gierstras telen. Deze verschillen zijn ongerelateerd aan sekse. In hoofdstuk 9 wordt beargumenteerd dat deze verschillen het resultaat zijn van complexe sociale verhoudingen. Uit het groeperingexperiment in hoofdstuk 9 blijkt ook dat mannen en vrouwen rassen op dezelfde manier onderscheiden.

Zaadstromen

Uit hoofdstuk 6 blijkt duidelijk dat boeren proberen zaadstromen te beheren. Het hoofdstuk laat zien dat verscheidene factoren zaadstromen beïnvloeden en bepalen. De belangrijkste factoren zijn verlies van zaaizaad, de behoefte aan nieuwe rassen (gerelateerd aan veranderingen in ecologische, sociaal economische en culturele factoren), en de aanwezigheid (of afwezigheid) van kanalen voor zaaizaad. In een traditioneel landbouwsysteem zijn deze kanalen familierelaties, vriendschappen, handelsrelaties en markten. Tegenwoordig vormt de formele zaaizaadsector een extra kanaal, alhoewel in dit kanaal zaad in een richting stroomt (naar de boeren toe). Omdat ongeveer een derde van de vrouwen buiten hun dorp trouwt, vormen deze familierelaties een belangrijk kanaal voor rijstzaadstromen tussen dorpen, terwijl in het geval van gierst, geteeld door mannen, er weinig zaaduitwisseling is tussen dorpen. Een tweede verklaring voor de weinige uitwisseling van gierstzaaizaad is dat er erg weinig gierstrassen zijn vergeleken met rijstrassen, wat betekent dat er ook geen reden is voor uitwisseling tussen dorpen. Voor rijst wordt het uitgewisselde zaad tussen dorpen gebruikt voor het testen van nieuwe rassen. Zaaduitwisseling binnen dorpen is voornamelijk bedoeld om verloren zaaizaad te vervangen. Rassennamen geven informatie over de mate van zaaizaaduitwisseling. In dorpen waar namen op een consistente manier gebruikt worden, is minder uitwisseling met andere dorpen, dan in dorpen waar namen niet op een consistente manier gebruikt. Namen geven ook informatie over de tijdspan dat rassen in een dorp gebruikt worden en over de mate van gebruik van deze rassen. Verschillen in naamgeving van rijst en gierstrassen kunnen verklaard worden uit het feit dat er gierstrassen minder vaak vervangen worden dan rijstrassen.

Pollenstromen

Vergeleken met zaadstromen worden pollenstromen niet bewust beheerd door boeren. Hoofdstuk 7 laat zien dat pollenstromen zeer verschillend zijn voor rijst en gierst. De belangrijkste factor is het kruisbestuivingpercentage, wat veel hoger is voor gierst dan voor rijst. Kruisbestuiving kan alleen leiden tot de ontwikkeling van nieuwe genotypen als het percentage kruisbestuiving niet te hoog is. Onderscheidbare, stabiele genotypen ontwikkelen makkelijker in gewassen met een laag kruisbestuivingpercentage, zoals rijst. Het is dus ook makkelijker voor boeren om off-types te selecteren in zelfbestuivende gewassen dan in kruisbestuivende gewassen. Andere factoren die de kansen beïnvloeden dat nieuwe stabiele genotypen zich ontwikkelen zijn de afstanden tussen velden, bloeiperioden, het aantal rassen in de naast elkaar gelegen velden en het aantal ingemengde rassen binnen velden. Boeren vinden het niet erg als er andere rassen in het zaaizaad vermengd zijn, omdat ze dat beschouwen als een soort verzekering. In hoofdstuk 7 blijkt dat voor rijst de kansen voor kruisbestuiving tussen rassen hoger zijn binnen velden dan tussen velden. Omdat bijna alle boeren binnen een dorp hetzelfde gierstras telen zijn de kansen op kruisbestuiving tussen rassen erg klein.

Hoofdstuk 8 laat zien dat, vergeleken bij pollenstromen tussen rassen, pollenstromen tussen gecultiveerde en wilde planten minder vaak voorkomt (meer voor rijst dan voor gierst), omdat wilde verwanten in lage aantallen voorkomen in verbouwde velden en ze vaak eerder bloeien dan de gecultiveerde planten. Bovendien zijn interspecifieke pollenstromen minder effectief vanwege genetische incompatibiliteit (meer voor rijst dan voor gierst). Boeren beheersen deze interspecifieke pollenstromen in een indirecte manier. Ze maken zich niet druk over wilde verwanten als ze in lage aantallen voorkomen in hun veld, waardoor ze op die manier enige pollenstromen toelaten. Wanneer wilde verwanten in hoge aantallen voorkomen in het veld en concurreren met het geteelde gewas, dan wieden de boeren deze wilde verwanten, waardoor de pollenstroom gereduceerd wordt.

In het algemeen denken boeren dat off-types veroorzaakt worden door god, en ze hebben geen goed begrip wat precies leidt tot verandering in rijst en gierst. Hoewel mannen en vrouwen hetzelfde begrip hebben van de ontwikkeling van vreemde off-types in gierst en rijst, testen mannen deze off-types niet, terwijl vrouwen ze wel testen en ze soms ontwikkelen in nieuwe rassen. Zoals eerder gezegd, ontwikkelen nieuwe stabiele en onderscheidbare off-types zich makkelijker in rijst dan in gierst. Onderscheidbaarheid is essentieel opdat boeren off-types kunnen opmerken. Het oogstproces vergemakkelijkt het opmerken van vreemde off-types in rijst meer dan in gierst. Daarnaast lijkt het dat het niet testen van vreemde off-types deel uitmaakt van de mannelijke identiteit. Mannen weten hoe verschillende plant-typen te onderscheiden, maar blijkbaar is dergelijke kennis niet belangrijk voor hun identiteit.

Het effect van genenstromen op aanpassingsvermogen en veerkracht

The tweede onderzoeksvraag was of genenstromen een rol spelen in het behoud van aanpassingvermogen en veerkracht van landbouwsystemen. In hoofdstuk 10 werd geconcludeerd dat processen die genetische diversiteit reguleren verschillend zijn voor gierst en rijst. Voor rijst spelen kruisbestuiving tussen rassen en de selectie van off-types een essentiële rol in de ontwikkeling van nieuwe rassen. Bovendien is zaaduitwisseling tussen dorpen cruciaal om genetische diversiteit op dorp en regionaal niveau op peil te houden, terwijl dit minder belangrijk is voor gierst. In gierst zijn kruisbestuiving binnen rassen en zaaizaadselectie de belangrijkste processen om genetische diversiteit op peil te houden. Het is dus waarschijnlijk dat genetische diversiteit meer fluctueert in tijd en ruimte voor rijst dan voor gierst. Het effect van kruisbestuiving en zaaduitwisseling op genetische diversiteit resulteert in het geval van rijst tot de ontwikkeling van nieuwe rassen, en in het geval van gierst tot het behoud van genetische diversiteit op populatieniveau.

In hoofdstuk 11 werd uitgelegd dat aanpassingsvermogen (en veerkracht) verkregen kunnen worden door genetische diversiteit en plasticiteit. Het hoofdstuk ging dieper in op de invloed van selectie op aanpassing aan lokale omstandigheden. Het blijkt dat gierstrassen niet heel lokaal aangepast zijn en dat raskeuze meer gerelateerd is aan culturele voorkeuren dan lokale aanpassing. Hoewel er geen gegevens zijn, is het aannemelijk dat rijstrassen ook relatief wijd aanpasbaar zijn. Voor rijst is een andere factor die een rol speelt bij raskeuze het tijdstip van introductie van een ras in een dorp in samenhang met de al aanwezige geschikte rassen in dat dorp.

Het is waarschijnlijk dat pollenstromen slechts een kleine rol spelen om populaties aanpasbaar te houden aan snelle ecologische veranderingen in de context van een landbouwsysteem. Dit betekent niet dat het proces van aanpassing door genetische evolutie genegeerd zou moeten worden, maar dat het proces te langzaam is vergeleken met de besluitvorming van boeren die binnen enkele jaren kunnen besluiten om van ras te veranderen.

Het belang van genenstromen

In hoofdstuk 12 worden de implicaties van deze conclusies voor het belang van genenstromen bediscussieerd. Onder langzaam veranderende omstandigheden draagt een hoog kruisbestuivingpercentage bij aan aanpassing op veldniveau, wat indirect bijdraagt aan aanpassingsvermogen op landbouwsysteemniveau. Onder snel veranderende omstandigheden (zowel ecologisch als socio-economisch) is ras uitwisseling essentieel voor het aanpassingsvermogen op landbouwsysteemniveau. Een laag kruisbestuivingpercentage draagt bij aan het aanpassingsvermogen van landbouwsystemen door de ontwikkeling van nieuwe rassen. Dus kan geconcludeerd worden dat voor gierst aanpassing (en verbetering) een meer gradueel proces is, terwijl dit voor rijst een proces van horten en stoten is. Gierstpopulaties passen zich langzaam aan de veranderende klimatologische omstandigheden in Gambia, terwijl rijstrassen vaak vervangen worden als ze niet meer voldoen.

Integratie van boeren en wetenschappelijke gewasverbetering

In hoofdstuk 12 worden ook suggesties gegeven hoe informele en formele gewasverbetering geïntegreerd kan worden in de context van Gambia. Het is echter ook duidelijk dat er mogelijkheden zijn om formele gewasverbetering zelf te verbeteren, vooral door betere financieren en het verbeteren van de capaciteit van NARI. Het is ook belangrijk om tweerichtingsverkeer in informatie en zaaizaad, en het lokaal testen van rassen te stimuleren. Omdat boerengewasverbetering veelal een willekeurig proces is, wat ook haar kracht is, is het moeilijk om het te verbeteren. Boerengewasverbetering is waarschijnlijk het beste te verbeteren door het te integreren met de formele gewasverbetering. Een manier om deze twee systemen is door middel van Participatieve Ras Selectie. Als met bovenstaande suggesties de formele gewasverbetering verbeterd wordt, heeft Participatieve Plantenveredeling geen grote voordelen binnen de context van Gambia. Het kan echter wel gebruikt worden om te reflecteren hoe conventionele veredelingsmethoden verbeterd kunnen worden. In de laatste sectie wordt benadrukt dat als formele gewasverbetering bepaalde gewastypen uitsluit, boerengewasverbetering een belangrijke rol blijft spelen, vooral in marginale, risicovolle gebieden. Een laatste opmerking is dat gewasverbetering alleen kan bijdragen aan het verbeteren van de landbouw vanuit een systeembenadering waarin getracht wordt de complexe processen te begrijpen hoe gewassen ontstaan en verbeterd worden.

About the author

Edwin Nuijten was born on February 7, 1972 in Roosendaal, The Netherlands. After completing secondary education at Thomas More College in Oudenbosch in 1990, he went to Wageningen to study plant breeding. During his MSc he specialised in selection methods and rural sociology. After two technical MSc theses (of which the second involved estimating the level of insect-pollination of *Dimorphoteca pluvialis* and studying progenies of interspecific crosses between *Crambe hispanica* and *Crambe abyssinica* at CPRO-DLO) he did a thesis on farmer seed selection in Kwazulu Natal in South Africa. Immediately after graduation in 1996 he went back to South Africa to work on a research project for the Agricultural Research Council in South Africa in which the researcher made an inventory, using participatory approaches, of the cultivation methods and varieties used for root crops in Kwazulu Natal. After working for a short period at a plant breeding company in the Philippines in 1998, he decided to go back to Wageningen and look for funding for a PhD to continue working on farmer crop development. Early 2000 he got funding from NWO-WOTRO for a PhD of which this thesis is the result. From July 2000 to March 2003 he conducted fieldwork in The Gambia.