Improving rice-based technology development and dissemination through a better understanding of local innovation systems

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Abstract
Agricultural research predominantly emphasizes adaptation to ecological conditions giving little attention to the ways local social organization and structure shape technologies and their dissemination. In this paper we present, with a focus on African rice (*Oryza glaberrima*), how, next to ecological factors, cultural norms, values and narratives shape the use and development of local technologies related to rice farming in six west African countries (The Gambia, Ghana, Guinea, Guinea Bissau, Senegal and Togo). From 2000 to 2008, data were collected using questionnaires, interviews, focus group discussions, field observations and on-farm field trials. Access to and the use of technology were organized in different ways depending on complex interactions between ecological, socioeconomic and cultural factors. Important local innovations resulted from emergent interactions between ecological, socio-economic and cultural factors. These interactions within farmer innovations systems need to be recognized and validated. We argue that, in order to understand the adoption of modern technologies, we need to recognize that societal organizations differ across regions. Therefore, we need to integrate social factors into models of technology development and dissemination.

Introduction

The green revolution failed in many areas of west Africa because of the ecological diversity, limited labor availability and a strong tradition of small-scale agriculture. Agricultural research focuses most on developing rice varieties adapted to local ecological conditions, hence the wide application of participatory variety selection (PVS) trials in extension programs. The local cultural and social aspects determining the acceptance of varieties and the development of varieties under farmer management remain invisible (Richards, 1996). To validate these local technologies, it is essential to assess the cultural, social and historic mechanisms that, along with ecological factors, have shaped these local technologies. As the cultivation of African rice (*Oryza glaberrima* Steud.) is understudied and neglected by science, it is entirely the product of farmer agency. Across west Africa, it is also strongly linked to the history and culture of farming communities. Therefore, this paper describes and compares the cultivation (and abandonment) of African rice in different regions of west Africa to illustrate how it has steered local innovation and technology adoption. Three case studies are compared: three ethnic groups in the Togo Hills in Ghana and Togo; the Mandinka rice farming system in The Gambia, Guinea Bissau and Senegal ; and the Susu farming system in maritime Guinea (Fig. 1). The results illustrate how farmers' history, culture and organization co-produce and shape agricultural technologies in different ways. As such, the results also provide a better understanding of the development and nature of the farmer varieties of interspecific background (farmer hybrids) described by Nuijten *et al.* (2009).

Methods

The results presented in this paper were obtained mainly through social science methods: in-depth interviews with key informants, informal and semi-structured interviews, questionnaires, and focus group discussions. Some data from farmer-led field trials testing farmer varieties of interspecific background (identified by Nuijten *et al.* 2009) are presented.

The Togo Hills

Research was conducted in two case study areas in Ghana (Akpafu Odomi and Lolobi Kumasi, 10 and 8 km north of Hohoe, respectively, in the Volta Region in Ghana) and one on the Togo side in 2007–2008. The Akpafu and Lolobi are minority groups that speak the so-called 'Togorestsprachen' (Westermann, 1954): different languages that are almost unrelated to the dominant Ewe language. These groups all seem to share some history as refugees (Nugent, 2002). The religion in the Akpafu area is Protestant. In the Lolobi area, the religion is an integration of Catholic and traditional religion. Historically, the Catholic missionaries that came to Lolobi showed respect for and interest in local religious practices: they saw the similarities rather than the contradictions.[1]

On the Togo side of the border, data were collected in four Ewe villages on the Danyi plateau: Elevagno, Xexatro, Meampaseam and Dafor — all active in upland rice cultivation. Although not a minority group and not speaking one of the *Togorestsprachen*, they can also be regarded as having a refugee history. During the cruel

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[1] According to Father Akpalu and catechist Leo at the catholic church of Lolobi Kumasi.

Figure 1. Map of the sub-region showing study areas (indicated by pushpins).

regime of King Agokoli of the Notse Ewe Empire, a lot of Ewe fled westward and settled, among other places, on the Danyi plateau (Laumann, 2005). The Danyi plateau is known for its poor and acid soils.

The Gambia, Senegal and Guinea Bissau

In The Gambia, south Senegal (Casamance) and north Guinea Bissau, case studies were conducted in Western Division (in 2000–2003, 2007 and 2008), region de Sedhiou (2007 and 2008) and Oio region (2007 and 2008), respectively. The villages in Western Division, The Gambia — Tujereng as principle site and Faraba, Janack and Kitti as additional sites — were selected on the basis of the extent of upland rice and late millet cultivation. The villages in region de Sedhiou (Bunjadu and Dar Silame) and Guinea Bissau (Kolosar and Djendur) were selected on the basis of variety exchange networks with the Gambian villages. With the exception of one village in The Gambia, Janack, all the villages in these areas are Mandinka villages, although the Gambian villages have considerable numbers of Jola who fled from the conflict in Casamance that started in 1981. In southern Guinea Bissau, in Tombali region, interviews were conducted with 12 expert farmers selected by Marina Temudo, an anthropologist who has worked in this region since the early 1990s.

Guinea

Data were collected in maritime Guinea. Field research covered three sub-prefectures (local levels of government) — Molota, Friguiagbé and Moussayah — in the prefectures of Kindia and Forecariah. Ten villages were selected and, on the basis of their proximity to each other, were grouped into three research sites. Villages of site 1 (Bokariya and Sangaran) were chosen because of their remoteness (about 90 km from Kindia, the regional capital) to learn about farmers' seed strategies and varietal selection practices in a situation of poor infrastructure, limited interventions of development organizations, and the absence of an important nearby market place. Villages of site 2 (Seifan and Dentègueya) were selected because of their proximity to the rice seed center of Kilissi and the Centre de Recherche Agronomique de Kilissi (CRAK), which is the national rice breeding unit. Villages of site 3 (Kinyaya, Hononkhouré, Tour, Yaya, Dandakhouré and Sinta) were selected because of their proximity to Kindia. The dominant ethnic group was Susu and the dominant religion was Islam.

Results

African rice is still actively cultivated in the Togo Hills in Ghana and Togo, in Guinea Bissau and Guinea, but was mostly found as a weed in farmers' fields in Casamance (south Senegal) and The Gambia. Diverse reasons and combinations of factors maintain the cultivation of *O. glaberrima*.

The Togo Hills

African rice used to be the staple food for the Akpafu, Lolobi and Ewe on the Danyi plateau at a time when war and uncertainty forced them to stay in the mountains, as this rice grows well on the hillsides. *Oryza glaberrima* is never grown mixed with other varieties, but is traditionally intercropped with cassava. Its rich nutritive value was confirmed by all farmers.

Lolobi Kumasi, Ghana: Oryza glaberrima *as a religious asset*

Although most of the rice cultivated in Lolobi and Akpafu now is red Asian rice, *O. glaberrima* is still grown in small quantities for customary rites, marriages and funerals. Red *O. sativa* dominates in the form of the variety Viono and can be seen as an extrapolation of African rice — Viono resembles *O. glaberrima* (Bouadekamo in the Sewu language) in many ways, especially in pericarp color, taste and cooking characteristics. It only differs largely in the shape of the grain, and in the shape of the panicle. In Akpafu and especially in Lolobi, white rice (mainly grown for sale) is often consumed mixed with some Viono, as red rice is strongly preferred over white rice. A farmer discovered Viono within another red variety. At the Kpong research institute (Ghana University), researchers were not able to classify Viono. Dr Koffi Dartey, who runs a rice program at the Crop Research Institute in Kumasi, stated that this variety was certainly not introduced by any research institute and was one of the local varieties found in the Hohoe area. It is sure that Viono has a farmer origin as scientific research has only very recently been developing red varieties (e.g. NERICA 14 and 18). According to farmers, Viono has been in the region since about 1990 and has spread all over the Volta region. Aworema is another promising red *O. sativa* variety that was discovered within Viono and is very similar to it, except that it has an upright leaf that protects the panicle against birds (Aworema: 'hiding from the enemy' in Sewu language). Aworema was discovered in Lolobi in 2006. This also explains the small share of Aworema in Akpafu (Table 1).[2] Table 1 shows the role of *O. glaberrima* (Bouadekamo), *Viono* and Aworema within the rice production of Lolobi Kumasi and Akpafu Odomi. In Accra, red rice (from the Volta region and from the north of Ghana) is becoming a healthy food product for the well-educated middle class (Teeken, unpublished).

Table 1. The share in production (%) of various red varieties and white rice in upland and lowland rice farming in 2007 and 2008 in Lolobi Kumasi and Akpafu Odomi villages, Ghana

	Lolobi Kumasi				**Akpafu Odomi**			
	Upland		**Lowland**		**Upland**		**Lowland**	
	2007	**2008**	**2007**	**2008**	**2007**	**2008**	**2007**	**2008**
No. farmers (N)	20	36	54	75	10	19	57	82
Red rice	92	100	61	65	93	70	82	85
O. glaberrima	39	76	9	4	24	13	2	2
Viono (*O. sativa*)	30	9	35	32	68	28	70	81
Aworema (*O. sativa*)	23	14	13	25	0	4	0	0
White rice	8	0	39	35	7	30	18	15

Source: Survey, 2008.

The importance of *O. glaberrima* in Lolobi is illustrated by the following remark by farmer James Asare:

> *The Boudekamo is like the chariot of the queen of England, until today they have not replaced the chariot with a car … we change varieties all the time and we abandon varieties all the time, so we have to have something that stays the same, something that would be recognized by our forefathers.*

In Lolobi Kumasi, Bouadekamo plays a very important role in offerings to ancestors and local gods. Viono cannot be used here! Also no other food crops are used for these ceremonies as the ancient staple food is Bouadekamo. At family level, Bouadekamo is used within offerings to the family stool and the family's symbol: an earth model with cowries. The family's stool is the stool of the ancient family head and is conserved and protected carefully and is seen as the receptacle of his or her soul. Within the family's symbol, each cowry represents the spirit of a celebrated ancestor of the family. At village level, Bouadekamo is also used as the only food to be offered to local gods. These gods are served by priests called *Mobia*. These are consulted to ask for prosperity and to solve problems. So, at family as well as at village level *O. glaberrima* is an important component attached to moral and physical well-being. The *Mobia* and traditional morals and rules (like the taboo days for farming: *Ikulu* and *Ipo*) of which they are part, are still important among the younger generation. This explains why the farmer hybrid Untufa (Nuijten *et al.*, 2009) that was evaluated with Lolobi farmers was highly desirable: because the variety resembles *Boudekamo* in grain and panicle shape and yields very well. Farmers stated that it can therefore surely be used for customary rites.

[2] According to Joshua Amankwah farmer at Akpafu Odomi, "The Akpafu are now starting to try it".

Akpafu Odomi, Ghana: O. glaberrima *as a cultural asset*

Among the Akpafu, the family rituals and the local gods have more or less become extinct. A strong 'anti-traditional religion' sentiment is present, which is totally absent in Lolobi. People who still perform rituals related to these gods are therefore openly called 'pagans'. However, *O. glaberrima* is still cultivated (although in smaller quantities than in Lolobi — see Table 1) for cultural reasons: it is part of funeral and marriage ceremonies and an important ingredient for dishes eaten at all special occasions. During marriages, funerals and other gatherings, the following is often stated and confirmed by others: "If you eat the local *fufu* made with rice flour you will learn to speak our local language [Sewu] very fast". However, this local dish called *Kamokra* that goes along with the local bean stew can often also be made with Viono.

Instead of 'religion', the rites and ceremonies that include *O. glaberrima* or Viono flour are explicitly considered as 'culture' and 'tradition' and are therefore no longer connected to the unknown, they are no longer lifted up to the level of the religious and are therefore less important in constituting the social norms and structure. For example, the traditional days of taboo to go to farm, *Ikulu* and *Ipo*, have almost lost their significance. African rice is no longer connected to the unknown as is the case in Lolobi Kumasi and is therefore no longer an essential symbol to the community (Durkheim, 1912). It has, however, become a cultural identity marker.

Danyi plateau, Togo: O. glaberrima *an important food crop*

On the Danyi plateau, rice is a crop purely used for home consumption/subsistence. *Oryza glaberrima* is the only rice that is cultivated, because it seems to be the only rice that thrives well when no fertilizer is used. On the Danyi plateau, ecological factors mainly determine the individual management of the different varieties of *O. glaberrima*.

During ceremonies and rituals for ancestors, *O. glaberrima* is not at all exclusively used. Other crops such as maize, cassava and yam are used as well. Almost all farmers (146 out of 150) stated that it does not matter what kind of rice variety is used in ceremonies as long as it has been cultivated on their land. *Oryza glaberrima*, with its specific plant and seed characteristics, has not become a religious symbol like in Lolobi.

The Gambia, Senegal and Guinea Bissau

In The Gambia, the south of Senegal (Casamance) and in the north of Guinea Bissau, Mandinka farmers have stopped growing *O. glaberrima*. The main reasons are the red bran or pericarp and the difficulty in pounding (milling by hand), which are related. It is the removal of the red pericarp that makes the pounding difficult. Mandinka farmers (but also farmers from other ethnic background living in the same region) have a strong preference for white rice. Women indicated that they had always preferred white seed color, even in the past when they cultivated Asian rice varieties with a red pericarp.

Another disadvantage is that the taste of African rice is considered nice only for certain dishes, like porridge and *munkoo* (small balls made of flour, traditionally made of the first harvested rice, and used for various ceremonies). Other disadvantages mentioned by a few farmers were low yield, lodging, earliness and poor tillering (Table 2). Yield trials conducted in The Gambia in 2001 and 2002 suggest that *O. glaberrima* does not perform worse than *O. sativa* (Nuijten, 2005). A survey conducted in the three case study areas in 2007 showed that an increasing number of Mandinka farmers consider *O. glaberrima* as something 'bad', but 'badness' is unrelated to agronomic or culinary aspects. The negative traits they mentioned were the erect panicle (8 out of 63 farmers) and 'they just do not like it' (7 out of 63). These answers were given particularly by younger women who have never cultivated it themselves.

In the past, the main advantage of *O. glaberrima* was its earliness. In The Gambia, older women say that *O. glaberrima* was cultivated up to the 1970s. In Casamance, women stopped cultivation in about 2005. The main reason to grow it was that it flowers early and it was the first rice to be harvested. In most cases they sowed it mixed in fields of *O. sativa*.

In the past, women of Tujereng village in the west of The Gambia preferred pounding *O. glaberrima* instead of '*findo*' (*Digitaris exilis*), which is even more difficult to pound. When men stopped growing *findo* (due to lack of labor: children started going to school), the cultivation of *O. glaberrima* also decreased.. This development started in the late 1950s.[3] In those days, the bad (moldy) smell associated with rice sold in shops also became less, as the turnover became faster. This likely coincided with the sharp increase in rice imports around 1970, which was another reason for women to stop growing *O. glaberrima.* Around 1970, the first early maturing non-*O. glaberrima* variety, named Kari Saba, was introduced in Tujereng. This variety was one of the first farmer hybrids introduced in The Gambia. The availability of early maturing varieties with a white or brown pericarp was another reason for women to stop cultivating *O. glaberrima*, and it is likely that the availability of these varieties led to a sharp decline in its cultivation. Nowadays, only a few, predominantly older, farmers grow it as a mixture in the field.

[3] According to Sanneh (personal communication, 2001), farmers started replacing *O. glaberrima* in the 1950s.

Table 2. Disadvantages of *O. glaberrima* mentioned by Mandinka female farmers in three case study areas in 2007

	The Gambia	**Casamance**	**Guinea Bissau**	**Total**
No. farmers	(21)	(20)	(22)	(63)
Seed color	7	9	13	29
Difficult pounding	4	7	8	19
Panicle does not bend	2	2	4	8
I do not like it	1	3	3	7
Bad taste	3	2	1	6
Too early	0	1	0	1
Low yield	0	1	0	1
Needs rain	0	1	0	1
Shatters	0	0	1	1
Itches	0	0	1	1
Few grains / panicle	0	0	1	1
Lodges	0	0	1	1
Does not swell when cooked	0	1	0	1
Does not tiller	0	1	0	1
Grains with husks remain after pounding	1	0	0	1
Difficult threshing	1	0	0	1
Dominates the seed if not rogued	1	0	0	1
No disadvantage	0	1	1	2

The abandonment of cultural beliefs may also play a role in the ending of the cultivation of African rice. In the region de Sedhiou in Casmanance, women still maintain some cultural notions related to rice cultivation (such as the idea that mixtures in the field can be sown by 'other beings' and should not be removed as this may cause problems in the future when the 'other being' wants to collect his/her rice). In this region, women stopped the cultivation of *O. glaberrima* only in about 2005, much later than those in The Gambia and northern Guinea Bissau. The men of the region de Sedhiou are considered to be very learned in the Koran, while their wives seem to maintain cultural ideas more than in The Gambia or Guinea Bissau. It is suggested that religion (Islam) plays a role, in a complex way, in the abandonment of *O. glaberrima* cultivation among the Mandinka (Linares, 2002).

Southern Guinea Bissau

In southern Guinea Bissau, African rice is still cultivated in the uplands. In this part of the country, a large diversity of ethnic groups occurs, resulting in a mosaic of villages with different ethnicities (Balanta, Nalu, Malinke, etc.). Many farmers also consider the red bran of *O. glaberrima* a negative trait, but they still cultivate it because they consider it to have a good taste. Another advantage mentioned by some farmers is its ability to grow on poor soils, and that it can grow in an upland field where *O. sativa* rice was cultivated the previous year. Positive agronomic attributes are the ability to prevent *O. sativa* from lodging and to influence the flowering period of *O. sativa*. A nutritional attribute is that African rice has the ability to cure people. A cultural advantage of African rice is its ability to protect the field against witchcraft. This was also reported for the Susu in northwest Sierra Leone (Longley, 1999).

Guinea

In the Susu area of maritime Guinea, like in Akpafu Odomi, ritual ceremonies in rice farming are now limited. Islamic religious practices are dominant. However, there is still a strong belief that 'rice yield' can be stolen by witches or the entire harvest stolen in the night by thieves. Specifically, the variety Saali Fore (*O. glaberrima*) is purposively mixed with other varieties (*O. glaberrima* as well as *O. sativa*) at sowing to prevent crop failure caused by witchcraft. Seemingly, the presence of Saali Fore in the field prevents harvested bundles from being stolen. It is well known in the area that one should never approach Saali Fore by night, even when it is stored at home. No other variety of *O. glaberrima* can replace Saali Fore for these purposes. Another practice, though limited in scope, was the use of local lemon fruit to prevent yield drop caused by witchcraft.

Seed mixtures

Farmers mixed on average three (range: two to four) varieties. Such mixtures, called *sumbu*, were made before sowing and should contain at least one *O. glaberrima* variety. However, 10% of the purposively mixed fields in 2007 were *O. sativa–O. sativa*. Otherwise, *O. glaberrima* represents on average 50% (range: 25–75%) of the mixture. It should be noted that a purposive mixture of *O. glaberrima–O. glaberrima* has not been observed in the study area. Farmers said they mixed seed for different purposes:

1. To protect the field against witches as previously mentioned. Only the variety Saali Fore is specifically concerned.
2. To assure a constant yield and prevent crop failure. In fact, by mixing varieties farmers expect that at least one of them will survive the unpredictable rainfall and the decreasing soil fertility. *Sumbu*, in this way is a food security strategy.
3. To ease harvest management: farmers say that *O. sativa* are generally light varieties, while *O. glaberrima* are heavier and stay longer in stomach. To reduce the quick consumption of certain *O. sativa* varieties such as Samba, Pode and Dalifode, which are very light but tasty, farmers mix them with *O. glaberrima* varieties, most often with Saali Fore and Tombo Bokary. Other upland *O. glaberrima* varieties found in the study area (e.g. Siiga and Saafary) were not used in *sumbu*. They were mostly cultivated as standalone varieties. *Oryza glaberrima* varieties used in *sumbu* were also cultivated as standalone varieties.

Table 3 shows the cultivation of *O. glaberrima* in the upland in southern lower Guinea from 2004 to 2007. *Oryza glaberrima* was a substantial part of rice cultivation, taking on average about 15% of the cultivated area. Fields planted with *O. glaberrima* were on average *not* smaller in size than fields cultivated with *O. sativa*.

Table 3. Characteristics of the use *O. glaberrima* in upland rice cultivation in southern lower Guinea

Year	No. fields measured	Total no. *O. sativa* varieties	Total no. *O. glaberrima* varieties	Percentage *O. glaberrima* (of total area)	Average field size with *O. sativa* (ha)	Average field size with *O. glaberrima* (ha)
2004	66	9	4	15	0.61	0.80
2005	86	5	5	18	0.54	0.53
2006	105	10	2	13	0.76	0.86
2007	170	13	5	15	0.69	0.67

Discussion

This paper makes a regional comparison of how socioeconomic, cultural, religious and ecological factors shape the cultivation of African rice (*O. glaberrima*), based on a number of case studies in west Africa. In certain areas, ecological factors are the most important in the continuous cultivation of *O. glaberrima* (Danyi Plateau, Togo); in others, its maintenance is almost fully explained by cultural and/or religious factors (Lolobi Kumasi and Akpafu Odomi in Ghana). In other cases, the ecological, socioeconomic and cultural factors interact, such as with the Mandinka in The Gambia, Casamance and northern Guinea Bissau, where the reduction in rainfall in the 1970s, in combination with the availability of good-tasting imported rice and alternative varieties of short duration led to a gradual abandonment of *O. glaberrima*. Among the Mandinka, *O. glaberrima* is something of the past, and it is gaining a new significance but in a negative way.

The reasons farmers gave in the case study areas in Guinea and southern Guinea Bissau for the cultivation and mixing of *O. glaberrima* indicate that its cultivation is shaped by ecological, religious and cultural factors in more or less equal measures. *Oryza glaberrima* is also used here to slow down the consumption rates of tasty *O. sativa* varieties by cooking them mixed with *O. glaberrima*.

Emergence and adoption of new farmer varieties

Regional differences in the appreciation of African rice can explain farmer responses to new technologies. The cultural and religious factors that maintain *O. glaberrima* within the Lolobi and Akpafu areas have steered farmers' selection and have resulted in the varieties Viono and Aworema. In Lolobi and Akpafu, religion and culture have opened up new windows for technology development.

A comparison of the case studies shows that the red pericarp is liked or disliked in various areas. Whereas farmer hybrids, like Untufa, are accepted in Ghana because they have a red pericarp and look like *O. glaberrima*, they are not accepted in northern Guinea Bissau, The Gambia and Senegal because they look like *O. glaberrima*, and have the same characteristics, in particular the red pericarp and erect panicle. Depending on the farming system and the wider social context, the red pericarp is a nutritional, gender, religious or cultural marker, and plays an important role in the acceptance or preference of rice varieties.

A better insight into the cultural values and practices in relation to the cultivation of *O. glaberrima* also allows us to better understand why the farmer hybrids, as described by Nuijten *et al.* (2009), developed along the upper Guinea coast but not in the Togo Hills. The mixing of *O. glaberrima* and *O. sativa* was and still is a common practice along the upper Guinea coast (from The Gambia to Sierra Leone). The absence of mixing *O.*

glaberrima and *O. sativa* in the Togo Hills has likely reduced the occurrence of crossing between the two species, as there *O. glaberrima* is cultivated only in pure stands to assure its purity, necessary in religious and traditional practices.

Conclusion

Alongside ecological factors, sociocultural and religious factors deserve attention in models of technology development and dissemination. *Oryza glaberrima*, an ancient crop, represents, in different ways, a past in the present in the case study areas across west Africa and embodies important values of historical consciousness and therefore is part of the social structure and order. In some countries, like Togo, Guinea and Guinea Bissau, ecological factors are more important in its maintenance. The case studies presented in this paper show that *O. glaberrima* is maintained, or abandoned, because different interactions between social and ecological factors exist. An important, renewing and challenging task for scientific research institutes can be to categorize and document and thus validate farmer material while not disconnecting cultural and historic data from the physical varieties. Next to newly developed varieties such as the NERICA series, popular farmer varieties can be tested and disseminated. This would also serve an important pan-African concept: doing justice and making visible African history and culture.[4] This history and culture has produced valuable mechanisms that have resulted in a great range of farmer varieties. Doing justice to the 'laboratories' of African farmers needs a new approach that includes not just ecological factors. By exploiting, taking advantage of subtle interactions between the social and the ecological at the local level, such a new approach might result in a whole new range of opportunities to increase rice production and improve food security in a rapidly changing world.

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[4] An important notion also expressed by Dr Papa Seck, Director General of AfricaRice, during the opening ceremony of the Second Africa Rice Congress on Friday, 15 January 2010.