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Updating Varietal Adoption in Impact Assessment: The Case of Nikwaha in Subsistence Cassava Production in Coastal Mozambique

by

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Report Series

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EXECUTIVE SUMMARY

The focus of this report is limited: we validate the projected adoption of a disease-tolerant variety by very poor farmers cultivating a staple food crop. In the late 1990s, the incidence of cassava brown streak disease (CBSD) reached pandemic proportions along Mozambique's northern coast. A brown-streak, tolerant variety named Nikwaha was quickly identified, multiplied, and disseminated to farmers in six coastal districts of Nampula Province to combat the increasing menace of CBSD. By the end of 2006, about 100,000 rural households were expected to have benefited from stem cuttings of Nikwaha. In an impact assessment four years after planting material was first distributed (McSween et al. 2006), the Nikwaha project by Save the Children and its partners was projected to generate a 75% rate of return on investment and a total economic impact between 29 and 65 million USD in net present value. The level of adoption which was projected at 15% of cassava-growing area in 2006-07 and was assumed to reach a ceiling level of 33-50% of adoption at the peak of its popularity was the key parameter conditioning benefits.

Based on a two-stage sample in four costal districts of Nampula Province, we estimated that Nikwaha accounted for about 18% of cassava-growing area in 2006-07. Adoption in an almost wholly subsistence environment was the outstanding feature of this varietal change. The multiplication initiative seems to have filled the profile with the recommended variety. Distance from village-level distribution centers did not play a significant role in conditioning diffusion as spatial variation in adoption from the source of planting material was not documented. Farmers appear to have switched from Calamidade, an erstwhile dominant variety that was super-susceptible to the expression of symptoms of necrosis in roots, to both Nikwaha and Namacarolina, a variety that is somewhat tolerant to Cassava Brown Streak Disease.

The survey results also generated several surprises that point to research directions. Adopters accepted Nikwaha more for its consumption characteristics than for its tolerance to CBSD. Some adopters believe that the tolerance of Nikwaha to CBSD is deteriorating over time, and there is solid evidence that 10-15 adopters in Nacala-a-Velha have responded to this perception by decreasing their cultivated area of Nikwaha. The strong demand for sweet varieties, such as Nikwaha, Capmpinche, and Cherenje, was unanticipated. Households that have adopted Nikwaha plant about half their cassava area to sweet varieties. Nikwaha does not appear to have any glaring weaknesses that would limit its future diffusion that is expected to eventually arrive at about one-third of cassava-growing area in Coastal Nampula by 2020.

Summing up, the authors of the impact assessment study got the projections right, but some of their collateral information and conjectures were wrong. It was fortunate that varietal tolerance was found in a sweet background that was strongly demanded by farmers.

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1. **INTRODUCTION**

The focus of this report is limited: we validate the projected adoption of a disease-tolerant variety by very poor farmers cultivating a staple food crop. In the late 1990s, the incidence of cassava brown streak disease (CBSD) reached pandemic proportions along Mozambique's northern coast (Hillocks 2003). The direct consequences of brown streak for food security are unmistakable: severe yellow-brown, corky necrosis that makes infected areas inedible especially for moderately to heavily damaged roots. In its simplest terms, brown streak results in farmers harvesting a crop that they can only partially eat.

Between 2002 and 2005, repeated sampling of plants in farmers' fields suggested that the infection rate among commonly grown varieties approached 85%. Most plants of existing farmer varieties showed symptoms of necrosis of at least one root in severely affected villages (McSween 2004). Compared to drought, CBSD is unlikely to make headlines because damage is chronic and does not appear to fluctuate sharply from year to year, damaged production does not enter the market, and the yield consequences of infection are not transparent. Yet brown streak annually costs poor cassava-consuming households in Mozambique tens of millions of dollars in damaged production and foregone consumption.

Tolerant (and, hopefully in the future, resistant) varieties are a practical means to make a large dent in the brown streak problem which cannot be controlled by other means. In Mozambique, a brown-streak, tolerant variety named Nikwaha was quickly identified, multiplied, and disseminated to farmers in six coastal districts of Nampula Province to combat the increasing menace of CBSD. Reasons for brown rot's resurgence in eastern and southern Africa are not well-documented scientifically, but in Mozambique, speculation has centered on a highly susceptible variety called Calamidade (Calamity) heavily distributed in a cyclone relief effort in the late 1990s.

Unlike most cassava varieties grown in coastal Mozambique, Nikwaha is sweet and known for its tolerance to several sources of biotic stress. Sweet cassava is harvested and boiled fresh, is typically eaten in the morning, or throughout the day as a snack food, or is prepared when a ”quick” food is needed (McSween, 2004). Bitter cassava, on the other hand, is dried, pounded into flour, and cooked into a stiff “porridge” to provide the starchy base for the main meals of the day. Because of these different uses (and because of different post-harvest processing requirements), sweet varieties are normally harvested more frequently in piecemeal fashion than bitter varieties.

Nikwaha is a partial solution to brown streak because it succumbs to the disease but does not express root symptoms. Nikwaha is a local variety that is native to Mozambique, but it was not cultivated in Northern Coastal Mozambique prior to the initiation of USAID-funded project by the NGO Save the Children and its partners in six districts in lowland Nampula Province. That work made a frontal assault on the increasing problem of brown streak via the distribution of tolerant varieties identified in research trials.

In an impact assessment four years after planting material was first distributed (McSween et al. 2006), the Nikwaha project by Save the Children and its partners was projected to generate a 75% rate of return on investment and a total economic impact between 29 and 65 million USD in net present value. Based on comprehensive field-survey data and conservative assumptions, the economic superiority of Nikwaha was reckoned at 25% per plant which was equivalent to about $70 per hectare at a median planting density of 3,000 plants.

The distribution program of Save the Children was well designed and effectively carried out. Most of the planting material of Nikwaha was supplied by Save the Children which sourced initial propagation material from the Southern Africa Root Crop Research Network (SARRNET) run by the International Institute of Tropical Agriculture (IITA) which together with IIAM, Mozambique's national agricultural research organization, was also involved in screening research that identified Nikwaha as a variety characterized by unusual tolerance to CBSD. By the end of 2006, about 100,000 rural households were expected to have benefited from stem cuttings of Nikwaha.

A sensitivity analysis shows that the projected rate of adoption was the parameter that conditioned the results of the cost-benefit analysis. Survey responses suggested that the early acceptance of Nikwaha was strong, but more research was needed to determine the coverage of Nikwaha. In particular, the extent of adoption was projected to be about 15% in 2006. Determining the accuracy of this prediction was viewed as the central issue in impact assessment and underscored the need for a follow-up adoption survey.

That survey was conducted in September 2007 in four of the six districts of Coastal Nampula where the Save the Children distribution project was active. Although the report has a very limited focus on updating adoption estimates, the survey generated other relevant information about the diffusion of Nikwaha.

A case study of the adoption of Nikwaha is relevant and interesting for two reasons. Firstly, the impact assessment of Nikwaha combined reporting of what happened in the early years with projections in the cost-benefit analysis. Few ex-post case studies of impact assessment are strictly historical; the vast majority mix ex ante and ex post assessment (Walker et al. 2008). Therefore, the Nikwaha impact assessment study is typical of this central tendency in impact of assessment of well-defined agricultural technologies. However, few if any of these studies ever go back and validate their projections. Reconciling ex-ante impact assessment with ex-post findings is an increasing priority in project appraisal (Boardman et al. 2001).

Secondly, the demand context for technological change is also rare. Usually, technological change is driven to some extent by market forces. Cassava processing into marketable products is increasing rapidly from a small base (Nweke et al. 2002), but commercialization of cassava and its products probably only accounts for 5% of total production in Coastal Nampula. Calling production semi-subsistence is an exaggeration at the existing level of commercialization. Introducing technologies in an overwhelmingly subsistence setting is a challenging task.

The report begins with a discussion of sampling strategy and ends with conclusions some of which are surprising. Themes pertaining to the adoption of Nikwaha and to varietal replacement and varietal characteristics are central to the report that returns to the main issue of adoption estimates prior to the concluding section.

2. THE SAMPLING STRATEGY, SURVEY CONTENT, AND RESULTS FROM THE LIST QUESTIONNAIRE

Estimating the level of adoption of the cultivar Nikwaha in several districts where the NGO Save the Children was working in the early 2000s was the objective of this survey research, which was carried out in September 2007 for the cropping year 2006-07. A two-stage approach to sampling was used to estimate farmer acceptance of Nikwaha.

Based on resource availability and the estimated variance in expected Nikwaha adoption, a sample size of 70 to 80 households in each of four districts was viewed as desirable.[1] Sampling was conducted at three administrative levels: district, administrative post, and community. Sampling was proportional to population.

In each district, two administrative posts were randomly selected. Within each administrative post, three communities were chosen: a central or ‘mother’ community and two remote or ‘daughter’ communities, one nearer (5-10 km) to the central community and the other more distant (10-20 km) from the central community. The sample size for each administrative post was 40 households comprised of 24 in the source community and eight each in the outlying communities.

The sampling scheme called for interviews in 4 districts, 8 administrative posts, and 24 villages yielding about 300 total questionnaires if, on average, 75 households were canvassed per district. This design was not followed to perfection. Two communities in one district and all communities in another district were not geo-referenced for lack of equipment. In one district, information on awareness of Nikwaha was not elicited punctually because the questionnaire was incomplete. In Mossuril, only one administrative post was surveyed. Therefore, the completed sample size was about 275 households.

The first stage in sampling required the elicitation of a one-page list canvassing about 80 households in the source community and 25 households in each of the outlying communities (Annex Table 1). From this list, about 1 household in 4 was randomly selected for the intensive 8-page questionnaire.

[1] This section relies heavily on a 4-page report that describes the sampling methods, constraints in carrying out the survey, and perspectives on the survey. This report is called “Relatório de estudo da difusão da cultura de mandioca, variedade e Nikwaha, nos distritos de Mossuril, Mogincual, Nacala-a-Velha e Memba, província de Nampula.” Two districts, Nacala Port and Mozambique Island, were not covered because of a lack of resources to carry out the work.

Two variables guided the sampling strategy. Save the Children started to distribute stem cuttings in 2002-03 in selected sites in coastal Nampula province. Distance from a village that figured as a distribution center of Nikwaha stakes was viewed as a potentially important factor in adoption in coastal Nampula, which is bereft of transportation infrastructure. We wanted to see if adoption followed a distance gradient because stakes are bulky and somewhat difficult to transport. Distance could affect varietal diffusion in a crop like cassava that is vegetatively propagated and, consequently, is characterized by a low multiplication ratio. Therefore, an effort was made to canvass households both in the village and in the outlying region of the center of distribution of planting material.

Findings on the importance of distance also have implications for the interpretation of the adoption estimate. Encountering adoption levels about the same for the three strata suggests that early adoption has been completed. The estimate could be considered as approaching a ceiling level of adoption. In other words, Nikwaha had thoroughly penetrated into the outlying regions of the distribution center. In contrast, negatively covariate estimates with distance indicate that planting material is constrained; early adoption is still taking place. In this case, the estimated level of acceptance does not reflect an expected higher ceiling level of adoption.

Knowledge about Nikwaha is the second variable that shaped the sampling strategy. Again, listed households could be divided into three strata: those who did not know about Nikwaha, those who knew about but did not adopt Nikwaha, and those who adopted Nikwaha. From a research perspective, information on the latter two groups is substantially more informative than information on the former group. Hence, scarce research resources addressed the groups that knew about Nikwaha, and households with knowledge formed the basis for sampling from the listed households. Households that had adopted Nikwaha were oversampled in the adoption survey. It is important to point out that the adoption estimate is constructed from the first-stage list that includes all households. This list provided the basis for estimating the expansion factors that, in turn, are the basis for the adoption estimates.

Questionnaires. In the first-stage of sampling, 1016 households were interviewed in four districts with a one-page questionnaire that contained preliminary information on household resource endowments, staple food crops, area under annual crops, the adoption of sweet cassava varieties, knowledge and use of Nikwaha, and membership in an association. From the listed households in the one-page questionnaire, about 1 in 4 households was sampled and interviewed with a survey instrument consisting of eight pages covering multiple household and field aspects potentially informing on the adoption of Nikwaha. Two hundred and seventy six households were interviewed from the listed households. Two of these households did not report any cultivated area, another household did have cultivated area but did not plant cassava, and one household did plant cassava but did not report information on varietal allocation by field. Therefore, the effective sample size was 272 households.

The use of 50 cowpeas to describe the relative importance of varieties in a field was one of the novel features of the survey research. A farmer allocated the cowpeas according to her or his perception of the varietal population in the field. This allocation procedure for estimating what is called 'relative space' in Portuguese was originated and validated for the problem of assigning relative importance to different crop species in fields characterized by associated cropping that are not row planted. Although row cropping is gradually increasing in popularity, associated cropping is still the prevailing mode of cultivation in Mozambique. The cowpea-allocation procedure has not been tested for its reliability in varietal estimation of relative importance, but there is no reason to think that it would work well for species and not work reliably for varieties. Indeed, it should be more accurate for varieties than for species because the farmer should have a clearer perception of proportions of stakes planted to each variety than to the relative importance of species in a field.

Results from the one-page list survey. The first-stage list 'population' was about evenly distributed across the four districts where Save the Children had worked most intensively (Table 1). More than 90% of the households viewed cassava as their staple food crop, and 97% cultivated cassava.

With a few exceptions, the estimated averages in Table 1 are similar to the central tendencies in past national rural household income surveys for Nampula province. The major outlier is the relative importance of women-headed households. Having about 1/3rd of households headed by women is typical of southern Mozambique with high rates of male migration and emigration, but this level is about 3-4 times higher than what is estimated in the nationally representative rural household income surveys for northern Mozambique.

About 1/3rd of households had adopted Nikwaha since it became available four years earlier in 2002, and between 25-30% of households were growing Nikwaha in 2006-07. These levels of early acceptance are higher than those anticipated in McSween et al. 2006. About half of the households knew about Nikwaha and were able to identify it in comparative drawings based on morphological characteristics.

The results in Table 1 reveal inter-district differences in adoption. Adoption was significantly higher than the mean 1/3rd level in Mogincual, and significantly below the mean level in Memba and in Mossuril. The majority of households in Memba had limited experience with sweet cassava varieties. In contrast, in Mossuril, farmers grew sweet cassava varieties, but Nikwaha did not figure prominently in those varieties.

A distance gradient in adoption was not evident (Table 2). Adoption of Nikwaha in the more distant villages was somewhat less than in the source communities, but significant differences in estimated adoption between the outlying villages and the source communities did not emerge. The only really striking difference in Table 2 was the higher incidence of female-headed households in the source communities and the outlying villages.

Table 1. Description of the listed households by district.

Description		Memba	Mogincual	Mossuril	Nacala-a-Velha	Total
Household observations		254	252	240	270	1016
Female-headed households (%)		41.3	32.5	23.3	38.5	34.2
Average cultivated area (ha)		.9	.9	1.3	.9	1.0
Cashews/coconut (%)		67.3	64.7	64.2	61.1	64.3
Livestock (%)		40.6	54.4	55.0	53.0	50.7
Staple food (%)	Corn	7.1	11.1	8.3	3.3	7.4
	Rice	.4	.0	.0	.0	.1
	Sorghum	2.0	.0	.0	.4	.6
	Cassava	90.6	88.9	91.7	96.3	91.9
Cultivate cassava (%)		96.5	94.8	99.6	97.8	97.1
Number of sweet varieties	0	62.9	17.6	7.5	41.7	32.9
	1	28.2	63.4	64.9	43.6	49.7
	2	8.2	15.1	18.4	14.0	13.9
	3	.8	3.8	9.2	.8	3.5
Grew Nikwaha (%)		22.8	57.9	16.7	32.6	32.7
Grew Nikwaha in the 2006-07 season (%)		16.9	51.3	11.4	30.4	27.7
Farmer Association Members (%)		16.9	9.4	9.2	17.6	13.4

Table 2. Description of the listed households by distance from the source community.

Description		Within the source community	5-10 km	10-20 km	Total
Household observations		563	222	231	1016
Female-headed households (%)		41.6	24.8	25.1	34.2
Average Cultivated area (%)		.9	1.1	1.1	1.0
Cashews/coconut (%)		62.5	64.0	68.8	64.3
Livestock (%)		41.9	55.4	67.5	50.7
Basic foods (%)	Corn	9.4	5.9	3.9	7.4
	Rice	.0	.5	.0	.1
	Sorghum	.7	.9	.0	.6
	Cassava	89.9	92.8	96.1	91.9
Cultivate cassava (%)		95.9	97.7	99.6	97.1
Number of sweet varieties	0	35.4	25.3	34.1	32.9
	1	50.6	48.8	48.5	49.7
	2	12.2	17.5	14.4	13.9
	3	1.9	8.3	3.1	3.5
Grew Nikwaha (%)		34.6	32.0	28.6	32.7
Grew Nikwaha in the 2006-07 season (%)		28.6	29.5	23.9	27.7
Farmer Association Members (%)		14.0	8.6	16.6	13.4

3. **ADOPTION OF NIKWAHA**

Although estimating levels of adoption is the primary focus of this report, the survey is a rich source of information on several facets of the adoption of a new cultivar in a staple food crop. In this section, we examine multiple aspects of adoption that range from a taxonomy of adopters to reasons for non-adoption. Our examination is based on the second-stage sample of 276 households that is comprised of 178 adopting and 98 non-adopting households. In the tables that follow in this section, the estimates from the second stage sample are adjusted to reflect the relative importance of each observation in the first-stage sample.

The adoption context warrants three comments. First, the NGO Save the Children started distributing stakes of Nikwaha in 2002-03; therefore, 2006-07, which is the reference time for the survey, represents the 5^{th} cropping year in the diffusion process. The timing of this inquiry would be characterized mostly as early adoption of a technology in the take-off stage of user acceptance (Rogers 1995). Secondly, adoption of Nikwaha takes place in a setting of subsistence agriculture. Less than 10% of cassava production is marketed in coastal Nampula where the processing of cassava is increasing from a very small base. As described in the introduction, this emphasis on subsistence is not that common for cassava in Sub-Saharan Africa, and it is rare for innovations in food crops in developing-country agriculture. Thirdly, adoption almost always refers to partial adoption. Few farmers would be willing to plant all their cassava area in sweet varieties in general and in one sweet variety, such as Nikwaha, in particular.

Classifying adopters over time. Information was elicited on adoption for three consecutive cropping years from 2004-05 to 2006-07 and earlier years which should correspond to 2003-04 and 2002-03. Two discrete outcomes, adoption and non-adoption, and four time periods, result in 16 potential adoption categories. Those 16 potential outcomes are aggregated into seven categories in Table 3. Full adoption refers to households that planted Nikwaha in each of the four-cropping year categories. New adoption 2004-05 refers to first use in that cropping year and implies continuing usage in 2005-06 and 2006-07. Intermittent adoption refers to households that cultivated Nikwaha in the most recent year but had not sown the variety in at least one intervening year since they first adopted. Disadoption is defined as planting Nikwaha in an earlier year but not in 2006-07.

The distribution in Table 3 seems to suggest a typical pattern of a successful variety in the early stage of diffusion. A substantial number of new households try the variety each year; the incidence of initial acceptance is greater than the incidence of disadoption. The unweighted rate of adoption (number of farmers Nikwaha for the second-stage sample is rising over time from 35% in 2004-05 to about 65% in 2006-07.

Table 3. Classifying adoption of Nikwaha by category.

Adoption category	N	%
Non-adoption	554	63
Dis-adoption[a]	16	2
Intermittent adoption[b]	35	4
New adoption in 2004-05	36	4
New adoption in 2005-06	34	4
New adoption in 2006-07	75	8
Full adoption[c]	128	15

[a] Tried Nikwaha in earlier years but didn't plant since 2005.
[b] Planted Nikwaha in 2006-07 but not in all years since first adoption.
[c] Planted Nikwaha in all years since first adoption prior to 2004-05.

Sources of planting material. Initially, most of the planting material of Nikwaha was supplied by the NGO Save the Children which sourced initial propagation material from the Southern Africa Root Crop Research Network (SARRNET) run by the International Institute of Tropical Agriculture (IITA). This supply triggered the initial diffusion process that was subsequently characterized by multiple sources of supply. Information on ten of these sources was elicited in the survey over the four points in time corresponding to the timing of adoption in Table 3. Four of these sources were more dominant than others and are displayed by time of adoption in Figure 1.[2]

[2] The possible sources were received from an farmer's association, purchased from a farmer's association, received from an NGO, bought from an NGO, used own seed, bought from a specialized private distributor, purchased from a store, bought in the market, received from a neighbor, friend, or relative, and received from another party not described above.

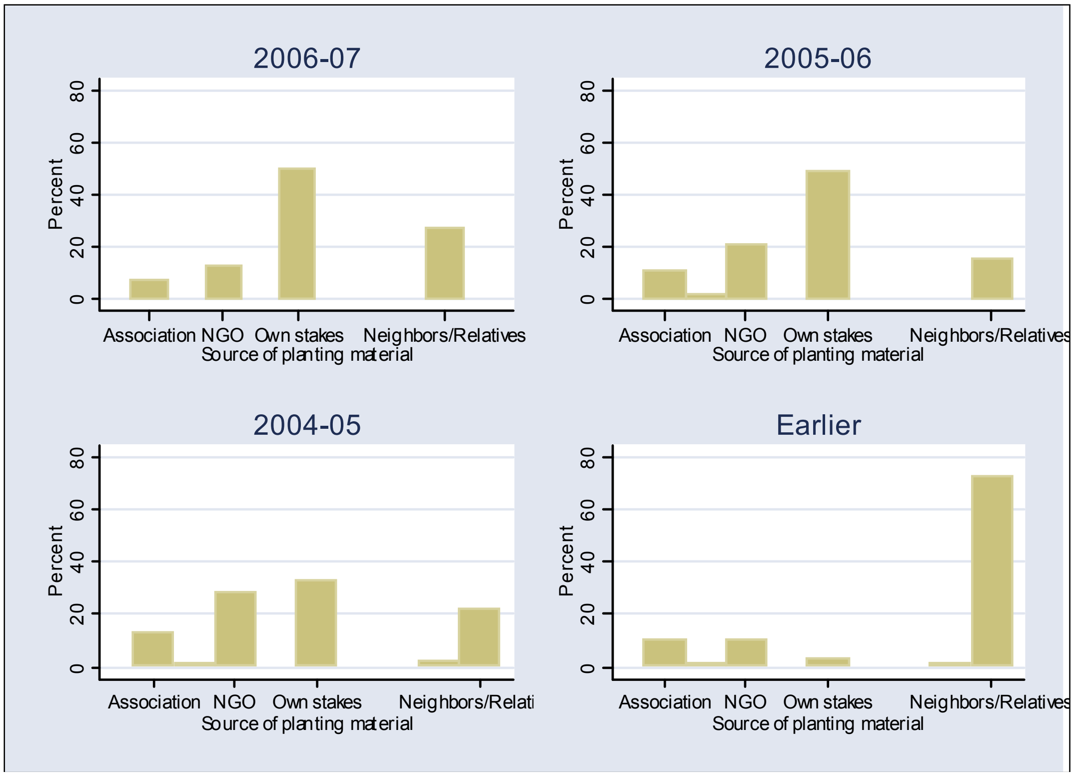

Figure 1. Sources of planting material for Nikwaha adopters over time**.**

Own seed, material freely available from Save the Children and farmer organizations, and stem cuttings from neighbors and relatives were considerably more important than other sources, such as purchased material from institutional and commercial sources including private individuals. The description of dominant and non-dominant sources and the changing importance of the four dominant sources over time in Figure 1 confirms several expectations and also generates some surprises. As expected, farmers' own seed looms larger as a source of material for propagation over time. By 2005-06, about 50% of adopters relied almost exclusively on their own produce for propagation material (Figure 1). Friends and relatives were the most important source of material in the diffusion of Nikwaha when the variety was first made available to farmers. Most new varieties diffuse farmer-to-farmer, and Nikwaha does not appear to be an exception.

But the overwhelming importance of friends and relatives as a source of material in the first two years (as described in Figure 1) is a bit puzzling. It was expected that adopters would have perceived a greater role for direct distribution by Save the Children and SARRNET in the initial year(s). However, this muted institutional response may reflect the success in establishing community-level, multiplication nurseries in 120 villages in 2002. Results from an earlier rapid adoption appraisal suggested that each of the community multipliers distributed material to 3-4 farmers each year (McSween 2004). Farmers who received material from the community multipliers may not have realized that the source was Save the Children or SARRNET as the material spread from farmer-to-farmer from beginning of the distribution program in December, 2002.

The strong role of institutional sources in the supply of planting material in the most recent year, 2006-07, is also unexpected. A more logical progression would be to see the importance of friends/relatives increasing and institutional sources decreasing over time. Institutional sources tried to fill the profile of propagation material several years after the initial material was distributed. Sustained institutional supply may have crowed out some adoption from informal sources, especially friends/relatives, but it resulted in increased early adoption.

Another surprise centers on the apparent lack of development of a market for Nikwaha planting material. Save the Children did distribute material from their distribution centers at a nominal cost to farmers (McSween et al. 2006), but the survey results suggest that little if any Nikwaha stem cuttings were transacted commercially. Propagation material of cassava varieties is rarely bought and sold; however, there appeared to be sufficient demand for Nikwaha to generate some commercialization of planting material because of the importance of planting material as a reason for non-adoption that is highlighted in the next sub-section. It is likely that the structure of the questions in the survey probably resulted in an underestimate of the commercialization of planting material that was not a focus of the survey. In contrast, the rapid adoption survey in ten villages documented that stakes of Nikwaha were sold for about 4 cents per U.S. dollar (McSween et al. 2004).

Reasons for nonadoption. Reasons for non-adoption centered around the lack of planting material. Respondents could cite multiple reasons for non-adoption[3], but few of these indicated perceived weaknesses in the characteristics of the variety or even lack of information about Nikwaha. Of the 624 responses, only 9 were consistent with a negative evaluation of Nikwaha in the sense that the respondent was not interested in planting it presumably because it did not compete well in his or her circumstances compared to varieties they were now growing. Over 90% of the responses addressed the scarcity of planting material. Non-adopters more than 10 km from the distribution center were more likely to cite lack of access as a reason for non-adoption than simply a lack of supply of planting material. Although adoption rates do not vary by distance (Table 2), this response suggests that access could still be a problem in remoter villages from the source communities.

The case for lack of planting material as a constraint to adoption receives some support from responses to a question on why some farmers were planting less area to Nikhawa over time. Six of the 25 farmers who were characterized by this behavior and who responded to this question said that theft was a major reason or a contributing factor. Theft is common when the demand for new varieties is robust.

The overwhelming emphasis on planting material in affecting the adoption of Nikhawa should be taken with several grains of salt. Knowledge of Nikwaha may be more

[3] Three questions were asked on reasons for non-adoption and they referred to the timing of non-adoption: never adopted, not adopted in the most recent year, and not adopted in prior years for those that had adopted in 2006-07. Five potential responses were offered for each of the three questions: did not know the variety, lack of access to planting material, lack of planting material, did not like the variety, and other reasons.

incomplete than a 6% response rate suggests. From drawings showing morphological characteristics of the variety vis-à-vis two other sweet cassava varieties, most non-adopters could not identify Nikwaha. (A few adopters could also not identify Nikwaha from the drawings). Farmers' responses could also be conditioned by their perception that institutional sources should supply planting material free of charge irrespective of the size of planting-material constraint. Nevertheless, the dominance of scarce planting material as a reason for non-adoption is surprising even for a vegetatively propagated crop with a low multiplication ratio. Unsolicited responses about theft in an open-ended question also reinforce the central message that demand for the variety is high and planting material is still a constraint.

Describing adopters and non-adopters. The Nikwaha survey focused on estimating adoption levels and did not entail a more conventional effort to examine determinants of adoption. Nonetheless, information on household characteristics was elicited and provides some explanation on adoption.

Household characteristics are described, in general, in Table 4.

Table 4. Description of household and field variables by category.

Variable	Category	Percent	Mean	Minimum	Maximum
Gender of household head	Male	81.9			
	Female	18.1			
Age of household head			39.5	16	77
Literacy	Literate	44.3			
	Illiterate	55.7			
Schooling (yrs)			2.4	0	12
Wage work	Yes	19.9			
	No	80.1			
Self-employed	Yes	30.5			
	No	69.5			
Agriculture primary occupation	Yes	89.0			
	No	11.0			
Farmer assoc. membership	Yes	15.0			
	No	85.0			
Family size	Total		4.0	1	9
	1-6		0.9	0	4
	7-12		0.8	0	5
	>13		2.3	1	6
Fields (number)			1.3	1	3
Cassava area (ha)			0.42	0.09	1.58

These characteristics are disaggregated in Tables 5a and 5b that build on the adoption classification in Table 3. Identifying tendencies in the adoption categories is difficult because of a small sample size in several groups, but several differences emerge in Tables 5a and 5b. Disadopters tend to be older men who are characterized by lower levels of literacy and schooling and who have higher participation rates in the market for wage labor but are less likely to be self-employed than other household heads in the sample. Disadopters and intermittent adopters seem to be less committed to agriculture than the other groups and also appear to have smaller family sizes. The four categories of continuous adopters over time are more literate than non-adopters. They are more likely to rely on agriculture as their principal occupation and, in general, are more likely to belong to a farmer association.

In order to look at differences in variables among adoption categories in a more systematic manner, five of the groups were considered as adopters based on their level of acceptance of Nikwaha in 2006-07. Two of the groups, non-adopters and disadopters, did not report use that of the variety in that year. Based a nonparametric Mann-Whitney rank sum test, we can identify variables which displayed statistically significant differences, i.e. we reject the hypothesis that they came from the same population. The mean levels of literacy, schooling, membership in an association, number of fields, and cassava-cultivated area were significantly higher for adopters than for non-adopters. None of the other Table 5a and 5b variables, including gender of the household head, were statistically significant in this non-parametric comparison. Hence, the tabular description in Table 5a suggests that female-headed households were as likely to adopt Nikwaha as the male-headed households.

Table 5a. Mean household characteristics by adoption category

Adoption category[a]	**Gender HH**[b] **(women)**	**Age (yrs)**	**Literacy (proportion literate)**	**Schooling**	**Family size**
Non-adoption	0.203	39.19	0.38	2.05	3.93
Dis-adoption	0.094	50.54	0.26	0.87	3.30
Intermittent adoption	0.193	44.05	0.58	3.72	3.30
New adoption in 2004-05	0.073	34.61	0.46	2.77	4.72
New adoption in 2005-06	0.153	34.66	0.78	4.54	3.97
New adoption in 2006-07	0.155	40.94	0.64	3.24	3.97
Full adoption	0.195	39.91	0.50	2.38	4.27
Grand mean	0.148	39.5	0.44	2.37	3.98

[a] Defined in Table 3
[b] Household head, proportion women

Table 5b. Mean household characteristics by adoption category

Adoption category[a]	**Farmer association member**	**Wage work**	**Self-employed**	**Agriculture primary occupation**	**Cassava area (ha)**	**Fields (number)**
Non-adoption	0.10	0.20	0.32	0.86	0.38	1.24
Dis-adoption	0.23	0.09	0.26	0.91	0.61	1.70
Intermittent adoption	0.28	0.43	0.17	0.80	0.53	1.73
New adoption in 2004-05	0.13	0.34	0.27	0.96	0.36	1.26
New adoption in 2005-06	0.29	0.13	0.34	0.97	0.49	1.34
New adoption in 2006-07	0.11	0.23	0.38	0.89	0.52	1.46
Full adoption	0.30	0.09	0.24	0.99	0.48	1.35
Grand mean	0.15	0.20	0.30	0.89	0.42	1.31

[a] Defined in Table 3

The mean differences in several of the variables, although statistically significant, seemed small. For example, the mean cultivated area of Nikwaha adopters was 0.48 hectares; a comparable estimate for non-adopters was 0.42 hectares. The median cultivated area was 0.41 for adopters and 0.35 for non-adopters. In plotting the cumulative distribution of area between adopters and non-adopters, the disparity in cassava area was most pronounced between the 25^{th} and 75 quartiles. The top end of the distribution was the same for both groups: 5% of households planted more than 1.0 ha to cassava. This finding suggests that the difference in cultivated area between the two groups was not driven by market demand characterized by larger growing areas.

The determinants of adoption. The differences among variables can be tested more formally in a conventional binary variable regression model that reports changes in probability as values of the independent variables change and other variables are kept at their mean levels. Such probit regression estimates are reported in Table 6 with the magnitudes of changes in probability (dF/dx), standard errors, confidence intervals, means of variables, and probabilities of statistical significance in terms of z values.

Although the model specified in Table 6 explains only a small proportion of the variation in adopters and non-adopters, the analysis of determinants confirms the importance of literacy, membership in an association, and number of fields (as a proxy for farm size) as significant correlates, if not influences, in the adoption decision. The relative importance of these variables can be inferred from the first column in Table 6. The overall observed probability of adoption was 0.60 and the predicted probability from the model was 0.61

for the unadjusted second-stage sample. Switching from an illiterate to a literate household head increased the predicted probability of adoption to about 0.75 at the mean levels of the other variables. Belonging to an association improved the odds of adoption by about the same amount, an increase of 0.17. Adding another field above the mean level of about 1.4 fields was associated with an increase in the likelihood of adoption of Nikwaha of 0.12.

Differences in the uptake of Nikwaha were not statistically significant between men- and women-headed households. Men sometimes had wives in different villages; this arrangement facilitated the distribution of planting material to the remoter villages.

Table 6. Determinants of adoption of Nikwaha using probit regression reporting changes in probability.

Category	**dF/dx**	**Std. error**	**Z**	**P>|z|**	**x-bar**	**[95% C.I.]**
Gender	-.07	.08	-0.91	.36	.81	-.23 – .08
Household median age	-.001	.002	-0.64	.52	40.60	-.006 – .003
Literacy	.15	.002	2.21	.03	.48	.02 – .28
Wage work	.02	.09	.28	.78	.19	-.15 – .20
Self-employed	-.06	.07	-.84	.40	.31	-.20 – .08
Agriculture primary employment	.20	.12	1.68	.09	.91	-.03 –.43
Farmer association membership	.17	.08	2.23	.03	.20	.02 – .32
Family size	.02	.02	1.15	.25	4.02	-.01 – .06
Fields	.13	.06	2.27	.02	1.38	.02 – .23
Nacala-Velha	-.005	.10	-.05	.96	.29	-.19 – .18
Memba	-.16	.10	-1.55	.12	.29	-.35 – .04
Mogincual	.16	.09	1.68	.09	.25	-.02 – .34

Observations P = .60
Prediction P = .61
Number of observations = 276
LR chi^2 (12) = 35.31
Prob > chi^2 = 0.0004
Pseudo R^2 = 0.0951
Log likelihood = -167.93

* dF/dx is for discrete change of dummy variable from 0 to 1 z and P.|z| are the test of the underlying coefficient being 0.

Two aspects about the statistical significance of the number of fields warrant comment. First, the estimate suggests that better off farmers – those with more fields – were more likely to adopt Nikwaha. However, none of these farmers are that well off; the overwhelming majority would fall below any reasonably constructed poverty line. Moreover, the number of fields only varies from 1-3 and no farmers cultivated more than a few hectares. Tiny holdings in a subsistence setting reflect the reality of hand-hoe agriculture in Mozambique.

Secondly, land is still abundant, if not that fertile, in coastal Mozambique. Farmers could have responded to Nikwaha by expanding their cultivated area in response to an economically rewarding variety. But one could posit the opposite: in response to greater tolerance to brown rot farmers could plant less cassava to attain a fixed consumption target.

The adoption of Nikwaha means that they could reallocate their scarce energy reserves, which are quickly exhausted when family members are ill, to other more productive activities. Under this thinking, adoption of Nikwaha would be a force to dampen area expansion which makes sense for technological change that results in less damaged production. With our data set, we cannot say how Nikwaha affected cultivated area.

4. PERCEIVED TRENDS IN UPTAKE, CBSD, AND THE DEMAND FOR VARIETAL CHARACTERISTICS

Adopters were over-represented in the second-stage sample to elicit information on farmer perceptions on the dynamics of Nikwaha use over time, on the durability of resistance, and on how Nikwaha performed vis-à-vis other varieties with regard to 11 important characteristics. The demand for varieties is ultimately about the demand for characteristics, and there are almost always perceived trade-offs in characteristics. Selecting priority traits while minimizing trade-offs is what plant breeding is all about in a practical sense.

Trends in the use of Nikwaha. Farmers who had adopted Nikwaha were asked whether their intensity in the use of Nikwaha was increasing, decreasing, or staying constant over time. About half the adopters responded that they were planting more stakes of Nikwaha over time, about one-fifth said that their use of Nikwaha was declining, and the remaining three-tenths stated that their use intensity had not changed over time. This finding suggests the scope for further expansion in the area sown to Nikwaha.

CBSD and Nikwaha. One determinant was investigated at length as a variable conditioning trends in the use of Nikwaha: the perception that CBSD is a problem in Nikwaha and whether or not it is increasingly perceived as a problem over time. The multiplication and on-farm trials of Save the Children found little or negligible evidence that Nikwaha manifested symptoms of the disease in its roots or that its tolerance to the disease was deteriorating over time.

Opinions of farmers seemed to be at variance with the findings in the trials. About half of 115 responding, adopting households felt that CBSD was a problem in Nikwaha (Table 7). The perception of CBSD as a problem in Nikwaha represented one of the few variables where distance mattered. That belief was stated with significantly greater frequency in the source than in the outlying communities (Table 7). Because Nikwaha was grown earlier in the source communities than in the remoter areas, its tolerance to manifesting symptoms in roots could be eroding over time, and this diminution in performance could have been more visible in the communities where it was first grown. This difference in perceived damage may be of interest to plant pathologists. However, information on year of first damage did not point to increasing severity of damage over time. Alternatively, farmers in the source community may have been more aware of the problem of CBSD because of the extension effort of Save the Children; therefore, their responses may have reflected this greater awareness irrespective of the perceived tolerance of Nikwaha vis-à-vis other varieties.

Table 7. Perceived incidence of CBSD by farmers who planted Nikwaha in 2006-07 and in earlier years.

Perceived incidence	Distance from the source community (%)			
	0 km	**5-10 km**	**10-20 km**	**Total**
Yes	62.8	34.3	37.3	51.4
No	37.2	65.7	62.7	48.6

At first blush, the belief that CBSD was a problem in Nikwaha did not seem to influence use. About half the households that cited CBSD as a problem continued to increase or at least maintain their area planted to Nikwaha. But, more tellingly, 19 of the 24 households that said that their intensity in planting Nikwaha was declining cited CBSD as a problem.

In order to analyze the subjective trend data more systematically, we grouped the increasing and constant outcomes together as one group. The declining trend adopters were the other group in this binary variable setting. The probit analysis in Table 8 shows that viewing CBSD as a problem was associated with about a 0.30 decline in the estimated probability of an increasing or constant trend response. Hence, the perception of CBSD appears to play a role in determining use intensity in Nikwaha. This result does not change if we add other regressors, such as those in Table 6, to the specification in Table 8. Indeed, none of the socio-economic characteristics in Table 4 are statistically significant in explaining the variation in the perceived household area trends of Nikwaha.

However, differences in district location explain some of the variation in the perception of CBSD as a problem in Nikwaha. This perception is more widely shared by households in Nacala-a-Velha than households in the other regions. Several households in Nacala-a-Velha have reduced their plantings of Nikwaha because they believe that CBSD is a threat. No other variables were statistically significant correlates of the perception of a problematic status of CBSD in Nikwaha.

Of the 64 household heads who stated that CBSD was a problem in Nikwaha, 41 were able to identify the degree of severity of the disease ranging from light (score=1) to severe (score=5). Information on severity was elicited from pictures of the five possible

Table 8. Perceived trend in Nikwaha use and the perception that CBSD was a problem.

Trend	**dF/dx***	**Std. error**	**Z**	**P>|z|**	**x-bar**	**[95% C.I.]**
Perceived problem of CBSD	-.30	.07	-2.60	.009	.56	-.34 - -.06

Observations P = .79
Prediction P = .81
Number of observations = 115
LR chi^2 (12) = 35.31
Prob > chi^2 = 0.0071
Pseudo R^2 = 0.0615
Log likelihood = -55.28

* dF/dx is for discrete change of dummy variable from 0 to 1 z and P|z| are the test of the underlying coefficient being 0.

states of disease damage[4]. The average score was 3.65 suggesting moderate expected damage. Scores of 2 and 3 indicate that much of the root can be saved. A score of 5 indicates that the root, for all intents and purposes, cannot be consumed. Regressing the trend in use on disease score provides further evidence that perceived problems of CBSD has resulted in reductions in use intensity for some farmers (Table 9). Farmers who believed that damage in Nikwaha from CBSD was heavy to severe (equivalent to a score 4.65) were significantly less likely to say that their planted areas to the cultivar had increased or stayed the same over time.

Table 9. Perceived trend and the severity of expected damage by CBSD in Nikwaha.

Trend	**dF/dx***	**Std. error**	**Z**	**P>|z|**	**x-bar**	**[95% C.I.]**
Severity of damage	-.32	.08	-3.74	.000	3.66	-.49 - -.16

Observations P = .66
Prediction P = .73
Number of observations = 41
LR chi^2 (12) = 18.40
Prob > chi^2 = 0.000
Pseudo R^2 = 0.3494
Log likelihood = -17.12

* dF/dx is for discrete change of dummy variable from 0 to 1 z and P|z| are the test of the underlying coefficient being 0.

Finally, in response to a question on the durability of the cultivar's tolerance, the vast majority of respondents who saw CBSD as problematic in Nikwaha said that the level of tolerance was diminishing over time. Only 4 of 60 respondents felt that the cultivar's tolerance was unchanged over time. Returning to the 25 respondents who had reduced their planting to Nikwaha, 13 cited CBSD as the primary reason for their behavior. Six said that theft of planting material played an important role for reduced planting intensity. The other six cited other reasons.

[4] The CBSD root symptom severity scale developed by the International Institute of Tropical Agriculture (IITA) consists of five levels, or scores, of severity, and these levels are defined as follows (McSween, 2004):

Score 1 – No visible discoloration
Score 2 – Small flecks of yellow/brown discoloration present
Score 3 – 2%-10% of the root cross section area with yellow/brown discoloration and corky necrosis
Score 4 – 10%-30% of the root cross section with yellow/brown discoloration and/or corky necrosis
Score 5 – >30% of the root cross section with brown/black corky necrosis

In general, these results were not anticipated. Yet, any greater manifestation of symptoms of the disease over time does not seem to have halted Nikwaha's upward diffusion path. Nonetheless, declining tolerance is a cause for concern and warrants greater research particularly in revisiting and diagnosing disease severity for selected households in Nacala-a-Velha.

Nikwaha and the Demand for Varietal Characteristics. Information on the main reasons for adopting Nikwaha was elicited from 183 adopting households in the second-stage sample. These reasons are scored on a 0-5 scale and ranked in Table 10 for the 11 varietal characteristics in the survey. A ranking of 1 means that the trait was the most important reason for the adoption of Nikwaha and it was scored 5. The code 99 was given to responses where the trait was not mentioned or where importance was lower than the fifth most important reason. In the arbitrary scoring scale, a rank of 1 was assigned a 5, a rank of 2 was given a 4, etc. Responses in the 99 category were given a zero in calculating the mean score which varies from 0 to 5 according to the ranked importance of the trait.

Table 10. Reasons for the adoption of Nikwaha by characteristic and by ranking.

		Rank by distribution of responses[a]					
Characteristic	**Mean score[b]**	**1**	**2**	**3**	**4**	**5**	**99[c]**
Sweet taste/no processing	4.31	129	24	11	6	2	11
General taste	2.38	46	35	14	10	4	74
Yield	1.73	10	44	16	18	8	87
Tolerance to CBSD	1.51	12	21	34	9	13	94
Drought Resistance	1.03	5	13	22	18	10	115
Cooking Time	0.92	1	16	23	11	9	123
Use of leaves	0.89	5	6	13	25	24	110
Flour quality	0.85	1	11	12	24	23	112
Length of the growing season	0.31	2	0	9	5	10	157
Drying time	0.26	0	5	3	7	4	164
Market-related	0.13	1	2	2	2	2	174

a Responses sum to 183

b Calculated on a scale from 0 to 5 where the most important characteristic received a 5 and unranked characteristics received 0.

c Characteristic was not ranked in the top 5 by respondents.

The majority of respondents adopted Nikwaha because it was a sweet variety and could be eaten in fresh form without processing. This consumption characteristic was followed by the widespread perception that Nikwaha tasted good. Tolerance to CBSD was somewhat important but, on average, it only ranked fourth in importance. Only about 1 adopter in 5 ranked tolerance to CBSD among the top two characteristics in importance.

Again, this result is surprising and suggests that Nikwaha is not as prized for its tolerance to CBSD as for its fresh-consumption characteristics.

Several traits in Table 10 were not viewed as important in the adoption decision. The least important characteristics included market-related aspects, drying time, and length of the growing season. These traits are either unimportant to farmers or Nikwaha is weak in these aspects vis-à-vis other varieties.

In an effort to quantify trait-specific weaknesses of Nikwaha, respondents who said that a specific trait was unimportant in the adoption decision were asked to compare Nikwaha to other varieties. Respondents could rank the relative performance of Nikwaha on the trait of interest as superior, inferior, or the same. Farmers could also opt for a do-not-know option if they did not have any beliefs on how the variety performed.

The results of this query probing for trait-specific weaknesses are tabulated in Table 11. Perceived trait-specific weaknesses are not evident in Table 11. For all traits, the incidence of a superior rating was greater than the incidence of an inferior rating. Overall, drying time was voted as a trait that could be called a weakness of Nikwaha. This seems logical because much of Nikwaha is consumed fresh so drying time is not as important as in bitter varieties. Comparatively and in terms of absolute numbers, Nikwaha did not score that well on length of the growing season which is complicated by the fact that non-tolerant varieties can be harvested early to reduce the incidence of CBSD damage in cassava roots. This strategy is not that effective because the farmers incur a sharp yield penalty when the growing season is shortened.

Table 11. Comparing Nikwaha's perceived performance to other cassava varieties with regard to unranked characteristics.

	Perception of Nikwaha relative to other varieties			
Characteristic	**Better**	**Worse**	**Equal**	**Don't know**
Drought Resistance	107	8	67	2
Sweet taste/no processing	5	2	2	2
General taste	63	5	54	0
Yield	42	8	61	15
Tolerance to CBSD	50	13	51	24
Cooking Time	42	4	120	24
Drying time	50	14	177	22
Flour quality	97	2	29	17
Use of leaves	46	11	85	2
Market-related	83	7	83	105
Length of the growing season	76	14	102	47

The high incidence of 'don't know' responses in the market-related category suggests that most adopters have never marketed Nikwaha or its products. The results in Tables 10 and 11 support the view that adoption of Nikwaha has taken place in a subsistence setting which, again, is a rare success story of varietal change even for a developing country setting.

Many varieties are characterized by one or two ‘Achilles heels’ that potentially limit their uptake. But weaknesses of Nikwaha are not visible in Table 11. Another way to shed light on strengths and weaknesses is to ask farmers to identify the cultivar that most excels in a particular trait. Response to this question of the best cultivar for a specific trait also did not uncover transparent evidence on the weakness of Nikwaha. A large number of farmers ranked Nikwaha as the best variety for many traits which is uninformative and unlikely to reflect reality. Of 947 trait-specific responses, Nikwaha was ranked as the best variety 508 times; another variety was mentioned on only 339 occasions. Perhaps farmers felt that a very positive Nikwaha response would result in the distribution of more planting material in the future.

Whatever the reasons for the overwhelming positive support for Nikwaha, the best-variety responses do show trait-specific differences that potentially point to strengths and weaknesses of Nikwaha. Four stereotypic and differing responses are presented in Figure 2. The first panel in the upper-right hand corner displays the generalized case of dominance of Nikwaha over all other varieties with regard to tolerance to CBSD. This distribution of responses suggests that farmers still regard Nikwaha (coded 901 in histogram) as the best varietal bet to tolerate CBSD. This dominance scenario for Nikwaha is repeated for drought tolerance, sweet taste, general taste, and use of leaves. In the earlier rapid appraisal of adoption conducted in 2005 (McSween 2004), farmers unanimously praised Nikwaha as having the best tasting leaves of any variety they grew. They also praised its roots for their good taste and ease of cooking.

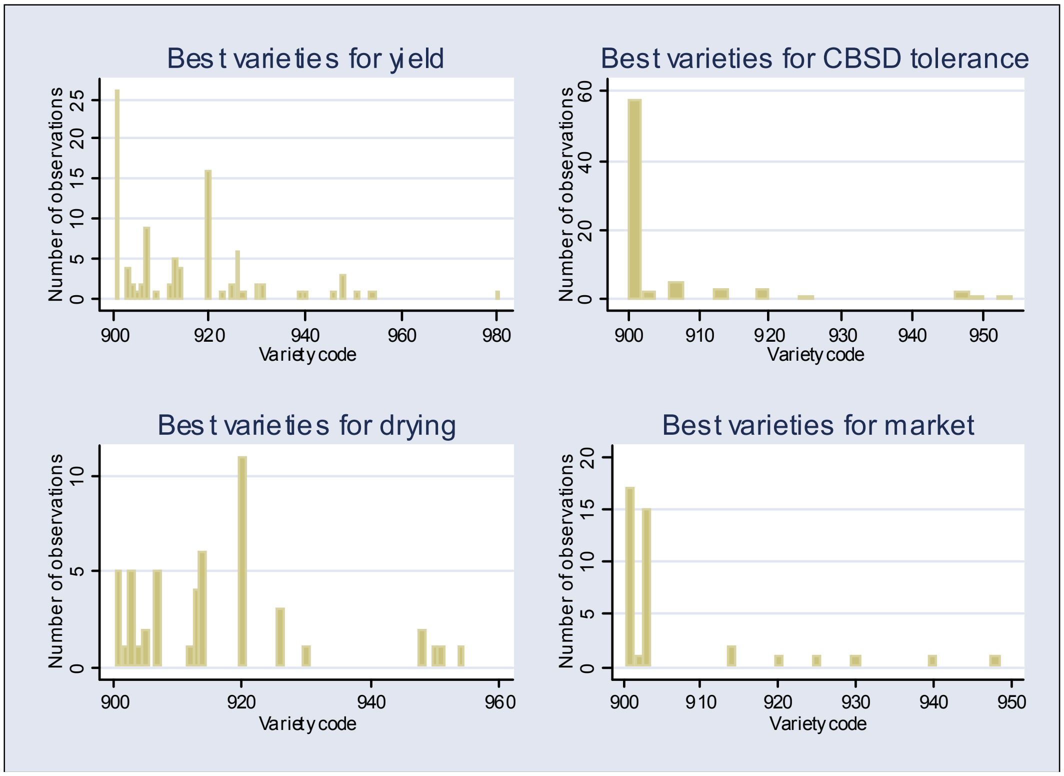

Figure 2. Frequency of varieties cited by farmers as best for selected characteristics.

The other three panels show characteristics where Nikwaha has competition and indicate areas of weakness. A prevailing sentiment was that other varieties were higher yielding particularly Namacarolina, coded 920. The same remarks apply to drying time. Several other varieties, including Namacarolina, were mentioned as the best. In the lower right panel, Campinche, code 903, rivals Nikwaha in market-related aspects for the few respondents who could make this comparison. Given the emphasis on Nikwaha in the survey, these results indicate that Campinche has greater market preference than Nikwaha.

Varietal preferences by trait were not as sharp as expected, but several varieties were mentioned as the best by at least 10 respondents. The most popular variety Namacarolina was prized for its yield, drying time, flour quality, and length of the growing season. The variety Campinche was mentioned for its sweet taste, cooking time, and market-related traits, Calamidade for its good taste and drought tolerance, and Nakwali for its drought tolerance. But none of these other varieties were chosen by large number of farmers as the overwhelming favorite for ‘best in characteristic.’

Non-response strengthens the above observation on somewhat blurred perceptions of characteristics. Of 2024 characteristic x respondent observations, positive responses were only registered for 847 observations or about 42% of the total. Apparently, many farmers do not have a clear favorite for the best variety in many of the selected characteristics.

Summing up, Nikwaha has the advantage of having an excellent background for a disease-tolerant cultivar. Such varieties can stay in farmers’ fields for a long time even after they lose their disease tolerance/resistance that was the initial motivation for adoption (Fonseca et al., 1996).

5. **VARIETAL REPLACEMENT WITH NIKWAHA**

Inferences about cultivar-specific varietal replacement and varietal diversity. We draw inferences on cultivar-specific replacement by comparing the varietal portfolios of non-adopters and adopters. It is assumed that the results of this without-and-with comparison mimic the findings from a before-and-after comparison. Given the time-varying dimensions of CBSD and varietal tolerances to the disease, this comparison is informative but flawed. Drawing on crop-cut data from 2002-05, several of its analytical weaknesses are highlighted later in this section.

Forty two local varieties were grown by farmers in 2006-07. Non-adopters showed a more diverse pattern of varietal concentration as a group than adopters. The distribution of relative importance for adopters was characterized by four distinct segments. The dominant variety, Namacarolina, laid claim to about 22% of the relative space in the farmers' cassava fields. Five varieties, Alapa, Tomo, Cocoro, Capmpinche, and Mphovakatwa, each accounted for 5-15% of unweighted area. Likewise, a handful of varieties were somewhat popular in the 2-5% range of area grown. The bulk (or 23) of the varieties were produced by only a small minority of farmers.

This same pattern is repeated for the adopters; however, Nikwaha is more dominant for adopters than Namacarolina was for non-adopters, and it, at 45%, accounts for a surprisingly large share of relative space. About the same number of varieties have non-zero outcomes, but more varieties contribute to a small percentage of relative area. These data reflect declining diversity in varietal use with the adoption of Nikwaha at the level of the adopters' and nonadopters' groups. But at the level of fields the finding on diversity is reversed: fields with Nikwaha are associated with more a greater number of varieties in a less concentrated pattern than fields without Nikwaha. The Simpson Index of Diversity is estimated at 0.54 for the Nikwaha fields and at 0.42 for the fields without Nikwaha.[5]

Over 90% of Nikwaha's gains came at the expense of the more widely grown important varieties in the non-adopters' portfolio (Table 12). Nine of the 11 most widely grown varieties lost significant ground with the adoption of Nikhawa. Several of these, such as Calamidade, Carita, and Mphovatakwa, showed high-levels of susceptibility to brown rot in the crop-cut data (McSween et al. 2006).

Comparing relative frequencies between samples and drawing implications for net benefit assessment. In the impact assessment study, McSween et al. 2006 estimated net benefits per hectare in switching from a 'susceptible' variety to Nikwaha at about $70/ha. Crop-cut surveys in farmers' fields between 2002 and 2005 were the basis for that estimate. Sampling for root weight and percent damage in the aforementioned IITA scale was conducted on a total of more than 15,000 plants over that four-year period. It was assumed that the crop-cut samples reflected relative varietal importance.

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[5] This index ranges from 0 for monoculture in one variety and approaches 1 for a large number of equally important varieties. The index is calculated as 1 minus the squared sum of the area shares of each variety in a field.

Table 12. Differences in varietal portfolios between non-adopters and adopters of Nikwaha.

	Importance (%)		
Variety	**Non-adopters**	**Adopters**	**Change (%)**
Namacarolina	22.30	8.97	-59.77
Mphovatakwa	11.84	3.20	-72.93
Capmpinche*	10.35	10.96	5.88
Cocoro	9.88	4.44	-55.04
Tomo	6.10	4.93	-19.09
Alapa	5.50	3.91	-28.84
Ntomeja	3.76	.47	-87.45
Namopuluko	3.55	1.17	-67.10
Calamidade	3.48	1.03	-70.31
Carita	2.11	.56	-73.39
Mpacua	2.10	2.83	35.00
Nivalapua	1.72	.29	-83.01
25	1.40	.22	-83.93
Pinto Machua	1.36	0	-100.
Guerra	1.34	.20	-84.93
Cherenje*	1.29	2.36	83.42
Salamathe	1.26	.31	-75.00
Inpuanaviga	1.19	0	-100.
Nagema	1.05	0	-100.
Nassuruma	.99	.17	-83.02
Beba/pepa	.91	.15	-83.92
Namaiche	.75	1.34	77.08
Garcia	.75	.71	-6.25
Ninatocolowa	.70	0	-100.
Nakwali	.66	0	-100.
Mmarrupa	.56	1.08	92.86
Chicomafia	.53	0	-100.
Inane	.50	1.69	234.82
Sao Tome	.45	.59	33.09
Ntheta	.43	0	-100.
Namaliti	.32	0	-100.
Visao Mundial	.31	0	-100.
Outros	.31	0	-100.
Nikeketche	.25	.20	-19.64
Nikwaha*	0	45.11	-
Murulaoahawa	0	.68	-
Buane	0	.65	-
Munachaga	0	.56	-
Mulaleya	0	.49	-
Italiano	0	.26	-
Niri	0	.25	-
Intesapuarro	0	.17	-

*Sweet varieties

Varietal importance for the crop-cut and the survey samples are compared in Table 13. For some varieties, like KoKoro and Tomo, the estimated percentages are similar but for others, namely Namacarolina and Calamidade, strong discrepancies emerge between the two data sources. These date suggest that Calamidade, one of the most 'susceptible' varieties in the crop-cut analysis, has lost ground in farmers' fields. By the same token, the popularity of Namacarolina appears to be steadily increasing. Namacarolina was one of the so-called 'best bet' varieties to CBSD with a somewhat higher tolerance with an average damage score of 2.80 compared to less tolerant varieties characterized by scores over 3.00 in 2004 (McSween 2004).

The increasing threat of CBSD most likely played a role in the rise of Namacarolina and in the demise of Calamidade. This dynamism in the counterfactual was predicted in McSween et al. 2006. Shifts to somewhat more tolerant varieties from Calamidade and other more susceptible varieties imply that the level of benefits would be overstated in later years if the level of benefits were estimated on the relative frequencies in the 2002-2005 crop-cut data.

To assess the amount of that overstatement we recalculated net benefits per hectare with the relative frequencies from the survey data in the last column of Table 13. The estimated damage root weight per plant declined from about 0.586 kgs to 0.510 kgs equivalent to about a 13% overestimate because of a failure to foresee the demise of Calamidade with or without the distribution of Nikwaha. This level of bias in impact assessment does not appear to be that large because the differences in tolerance among the local varieties are measured in degrees and not orders of magnitude. In contrast, Nikwaha's level of tolerance to CBSD was significantly higher than the other varieties. The difference in the estimated probability of damage was 10 fold less for Nikwaha at 5% compared to a mean level of about 50% for the other varieties in 2005 (McSween et al. 2006). Moreover, farmers valued Nikwaha for consumption attributes that were not valued in the cost-benefit analysis.

Table 13. Comparing the varietal importance between the crop-cut and survey samples of local varieties.*

Variety	Cross-cut sample (%) 2002-05	Survey sample (%) 2006-07
Nacuali	.94	1.02
Namacarolina	3.09	32.41
M'pacua	7.40	3.05
Kokoro	16.45	14.40
Nassuruma	4.54	1.45
Nivalupua	4.11	2.47
N'lapa	13.18	7.99
Guerra	1.90	1.89
Namiche	1.83	1.16
Buana	2.78	0
Carita	4.19	3.05
M'phovatacua	1.94	17.15
Tomo	8.81	8.87
Calamidade	28.83	5.08

*Relative importance of the major varieties in the cross cut sample between 2002 and 2005; many minor varieties are not included in this table.

6. IMPLICATIONS FOR ESTIMATING ADOPTION LEVELS AND CEILINGS

Estimating the adoption level of Nikwaha in 2006-07 and its prospects for the future is the core focus of this paper. Weighted adoption estimates that correct for the oversampling of the adoption households are presented in Table 14. The mean area planted to Nikwaha per adopting household was 0.28 ha. The mean area of Nikwaha per household in the sampling population was 0.096 ha that represented 18% of cassava area. For 2006-07, the projection from the impact assessment study was 16% which is close to the survey estimate (McSween et al. 2006).

The uptake of Nikwaha has been widespread. Planting material has penetrated into the remoter countryside, and the prospects for increasing adoption are bright. Only five years after its introduction, Nikwaha was the second most popular variety in the districts in coastal Mozambique where Save the Children was working. This strong performance still shows room for expansion, but it is debatable whether Nikwaha will reach a 50% ceiling level of adoption in the base scenario in the impact assessment study. A ceiling level of 30% seems readily achievable. At that level, the simple sensitivity analysis in the impact assessment study still showed high rates of return and net present values to the research and extension effort that resulted in the distribution of Nikwaha (McSween et al. 2006). Summing up, the adoption record of Nikwaha is outstanding in a subsistence agricultural setting where market demand has played only a negligible role in uptake.

Table 14. Varietal adoption by adopting households, total households, and total area.

Variety	Adopting households		Total households	Total area	
	Number	Mean area (ha)	Mean area (ha)	ha	%
Nikwaha	297	.280	.096	83.4	18.0
Calamidade	64	.184	.014	11.8	2.5
Capmpinche	253	.186	.054	47.1	10.2
Carita	18	.355	.007	6.4	1.4
Cherenje	22	.413	.010	9.1	2.0
Chicomamafia	8	.191	.002	1.6	.3
Cocoro	117	.273	.037	31.8	6.9
Guerra	28	.138	.004	3.9	.8
Italiano	2	.267	.001	.5	.1
M’pacua	61	.169	.012	10.3	2.2
Alapa	111	.227	.029	25.3	5.5
Mphovatakwa	140	.266	.043	37.4	8.1
Mulaleya	3	.528	.002	1.6	.3
Murulaoahawa	12	.075	.001	.9	.2
Nakwali	5	.150	.001	.7	.1
Namacarolina	247	.380	.108	94.0	20.3
Namliti	9	.061	.001	.6	.1
Nassuruma	25	.107	.003	2.7	.6
Nagema	9	.280	.003	2.5	.5
Nivalapua	10	.455	.005	4.6	1.0
Tomo	140	.182	.029	25.4	5.5
25	7	.602	.005	4.3	.9
Inane	25	.114	.003	2.9	.6
Buana	7	.108	.001	.8	.2
Inpuanaviraca	4	2.125	.009	7.8	1.7
Sao Tome	16	.169	.003	2.6	.6
Munachaca/Unachaca	7	.095	.001	.7	.1
Beba/Pepa	12	.448	.006	5.3	1.1
M’marrupa	13	.184	.003	2.3	.5
Salamathe	16	.253	.005	4.0	.9
Pinto Machua	23	.121	.003	2.8	.6
N’natocolowa	2	.180	.000	.3	.1
Garcia	15	.218	.004	3.3	.7
Ntomeia	32	.216	.008	7.0	1.5
Nakamula	2	.330	.001	.5	.1
Namopuluko	54	.177	.011	9.5	2.1
Namuiche	22	.089	.002	2.0	.4
N’theta	8	.136	.001	1.0	.2
Nikeketche	5	.140	.001	.7	.2
Intecapuarro	1	.180	.000	.3	.1
Niri/Niro	1	.167	.000	.2	.0
Visao Mundia	8	.084	.001	.7	.1
Others	9	.269	.003	2.4	.5

7. CONCLUSIONS

The results of the follow-up adoption surveys have reinforced conventional wisdom in some cases and generated several surprises. Results that support conventional wisdom are:

- adoption estimates for Nikwaha from the survey are as high as projections from the impact assessment study for 2006-07;
- distance from the distribution center did not play a significant role in adoption levels;
- some household traits such as literacy and membership in an association were positively and significantly associated with adoption;
- farmers appear to have switched from Calamidade, an erstwhile dominant variety that was super-susceptible to the expression of symptoms of necrosis in roots, to both Nikwaha and Namacarolina, a variety that is somewhat tolerant to Cassava Brown Streak Disease (CBSD);
- the steady increase in the uptake of Nikwaha has not been accompanied by a sharp fall in biodiversity

Surprising results are:

- adopters accepted Nikwaha more for its consumption characteristics than its tolerance to CBSD;
- some adopters believe that the tolerance of Nikwaha to CBSD is deteriorating over time and there is solid evidence that 10-15 adopters in Nacala-a-Velha have responded to this perception by decreasing their cultivated area of Nikwaha;
- the strong demand for sweet varieties, such as Nikwaha, Capmpinche, and Cherenje, was unanticipated. Household that have adopted Nikwaha plant about half their cassava area to sweet varieties;
- Nikwaha does not appear to have any glaring weaknesses that would limit its future diffusion. Not finding at least one significant weakness is rare;
- farmers appear to have blurred perceptions on the trait performance by varieties in cassava amongst the local varieties; varieties that were 'best-in-characteristic' were hard to name;
- availability of planting material seems to substantially influence planting decisions in an environment where perceptions on demand for characteristics seem fuzzy for most varieties;

Summing up, the authors of the impact assessment study got the projections right, but some of their collateral information and conjectures were wrong. It was fortunate that varietal tolerance was found in a sweet background that was strongly demand by farmers. Nikwaha is not the only case where researchers and farmers' perceptions of demand were not strictly congruent. Selecting for disease resistance and tolerance in a strong background can compensate for a multitude of sins particularly when resistance breaks down or tolerance deteriorates (Fonseca et al., 1996).

The results of the follow-up adoption survey also highlight several areas for research that are addressed in the following questions?

- Why is the demand for sweet varieties increasing now compared to the recent past and if there was demand in the past why was that demand not satisfied?
- What is happening to the tolerance of Nikwaha to the expression of CBSD symptoms in Nacala-a-Velha?
- Why does CBSD appear to be more of a problem in the minds of researchers than in the minds of farmers?

The last question in no way diminishes the importance of CBSD as a problem. These three questions call for some innovative diagnostic research by plant pathologists and social scientists. Like most successful research endeavors, the follow-up survey generated one definitive answer and several relevant questions for future research.

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Annex Table 1. **List of district, administrative posts, and communities in the sample and sample size by distance from the central community.**

District	P. Admin	0 km Comm. name	List (n)	Nikw (n)	5-10 km Comm. name	List (n)	Nikw (n)	15-20 km Comm. name	List (n)	Nikw (n)
Memba	•Cava	Cava	81	18	Imale	28	9	Tipaia	35	7
	•Memba-sede	7 de Abril	73	24	Miaja	25	8	Natepo	23	6
Nacala-a-velha	•Covo	Movie	82	31	Covo	23	5	Nacurula	25	4
	•Nacala-a-velha	Mueria	82	26	Patone	29	16	Micolene	27	4
Mogincual	•Liupo-sede	Maquela	81	48	Matico	16	11	Muerade	20	16
	•Quixaxe	Quixaxe	81	32	Nanluco	28	19	Mutela	26	14
Mossuril	•Ampivive	Ampivive	82	38	7 de Abril	28	6	Pedreira	82	8