

# Cassava Disease Surveillance Surveys 2009

## *Mapping Report*

### Great Lakes Cassava Initiative



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# 1. Introduction

## Project Background

The Great Lakes Cassava Initiative (GLCI) is a project financed by the Bill and Melinda Gates Foundation which has the primary aim of providing improved disease-free cassava planting material to more than 1.15 million farmers in six countries of the Great Lakes region of East and Central Africa. Target countries include: Burundi, Democratic Republic of Congo (DRC), Kenya, Rwanda, Tanzania and Uganda. The virus diseases – Cassava Mosaic Disease (CMD) and Cassava Brown Streak Disease (CBSD) – are the two most important constraints currently affecting cassava production in this region. Consequently, a central part of the GLCI Project involves combating these two diseases through a range of measures. These include: identifying and disseminating resistant varieties; assuring the health of cassava planting material through the multiplication and dissemination cycle; enhancing knowledge of the viruses causing the two diseases and monitoring their spread; improving diagnosis of the causal viruses; and strengthening knowledge of all stakeholders about the diseases. GLCI is co-ordinated by Catholic Relief Services (CRS), with support from the International Institute of Tropical Agriculture (IITA) and its partners in the implementation of the ‘Disease Objective’, one of five project objectives.

## Monitoring Cassava Virus Diseases

Effective management of CMD and CBSD depends on a sound understanding of the status of the two diseases in each of the target countries, and their patterns of regional spread. Knowing which regions are worst affected, and which are currently threatened is vital for the effective targeting of control interventions. Monitoring of CMD and CBSD is achieved in GLCI using two approaches. The first approach involves annual researcher-led surveys of farmers’ cassava fields through Project target areas. Detailed and reliable data are collected through these extensive surveys, but the cost is relatively high and the frequency is therefore necessarily limited to once per year. A second approach has been piloted in the Lake Zone of Tanzania. This is referred to as the Digital Early Warning Network (DEWN) and comprises a network of trained farmer groups that provide monthly reports on the status of cassava diseases in their fields through mobile phone-generated text messages (SMS). This is a much less intensive approach, but through the decentralized approach taken, it facilitates cheaper and more frequent collection of disease data. The two approaches are complementary, and when combined, provide a comprehensive and current picture of the status of the two cassava diseases in areas assessed.

## Annual Cassava Virus Disease Surveys

Annual pest and disease surveys were conducted by NARS teams in each of the six target countries in 2009 (Annex 1). Prior to the implementation of the surveys, meetings were convened to produce a standardized protocol, and to practice the methods developed. The approach used was based on earlier survey methodologies used by IITA and its NARS partners (Sseruwagi *et al* 2004). Comprehensive details of the survey methodology are provided in the survey protocol document, which is provided as an annex to this document (Annex 2). Surveys in each of the countries were led by their respective NARS which are:

- Burundi – Institut des Sciences Agronomiques du Burundi (ISABU)
- DRC – Institut National des Etudes et de la Recherche Agricole (INERA)
- Kenya – Kenya Agricultural Research Institute (KARI)
- Rwanda – Institut des Sciences Agronomiques du Rwanda (ISAR)
- Tanzania – Tanzania Root and Tuber Crops Programme (TRTCP)
- Uganda – National Agricultural Research Organization (NARO)

Surveys were conducted in each of the target countries between May and September 2009. In Rwanda, a different methodology was used, meaning that only some of the data were comparable with datasets from other countries. Full datasets were available for Burundi, DRC, Kenya and Tanzania and entered into a standardized data template in Microsoft Excel. Summaries of the data obtained from this were then used to develop the maps presented in this report.

## 2. Methods

### Sampling Framework and Data Collection

Details of the sampling approach and a full methodological background describing all data variables and their assessment methods are provided in Annex 2. Annex 2 also includes the forms used for data collection during the annual surveys. The sampling system used is briefly summarized here.

Sampling was organized using the administrative unit of the district, where present, or its equivalent in countries that do not use the district designation. Hereafter, we refer to these administrative units as ‘districts’. Within each of the target ‘districts’ in surveyed countries, two types of fields were assessed. Young fields, 3-6 months old, and old fields, more than 10 months old. Young fields (30 plants) were assessed primarily for foliar symptoms and abundance of virus vector populations, whilst old fields (10 plants) were assessed primarily for symptoms of CBSD in tuberous roots. In all surveyed ‘districts’, 15 young and 10 old fields were sampled.

Fields were sampled at regular intervals along motorable roads running through target districts. The sampling interval was determined by dividing the approximate total length of roads to be traversed through a district by the number of sampling sites.

At each sampling location, site information was recorded at the outset, together with GPS coordinates that were obtained using a Garmin Etrex HC unit.

A wide range of data variables were recorded during the field assessments. For the Young Fields, these included: whitefly adult abundance (*Bemisia tabaci*), whitefly nymph abundance, whitefly physical damage, whitefly sooty mould damage, cassava green mite (CGM) damage, incidence of the mite predator *Typhlodromalus aripo*, cassava mealybug (CM) damage, CMD infection type and symptom severity, CBSD foliar symptom severity and incidence of stem symptoms, and cassava bacterial blight (CBB) damage. For the Old Fields, data recorded included: CBSD foliar symptom severity and CBSD stem symptom incidence. Most importantly, a detailed assessment was made of CBSD symptoms in ALL roots of ALL (10) plants by making five cross-sectional slices at evenly-spaced intervals along the length of each root. Symptoms were then scored for each cross-sectional cut.

Data summaries were produced for all variables assessed, but only those of greatest interest were used for the development of maps. Mapped variables include all of the CBSD and CMD data, adult whitefly abundance, CGM damage severity and the occurrence of ‘improved’ cassava varieties – obtained from the site summary information. Combinations of CMD and CBSD variables were used to produce indexes of priority for the two diseases individually and combined.

## GIS Mapping

During the surveys the locations of the Young Fields and the Old Fields were marked with coordinates (Table 1). Individual sampling locations, showing CMD or CBSD incidence, are presented in maps 10 and 11. All other maps are based on averages of the sampled fields in the particular district. For the severity measurements only diseased plants were included in the average. For Uganda and Rwanda no individual site values were available, and district averages were copied from the GLCI country reports.

**Table 1: Number of districts and sites sampled. GLCI annual surveys, 2009**

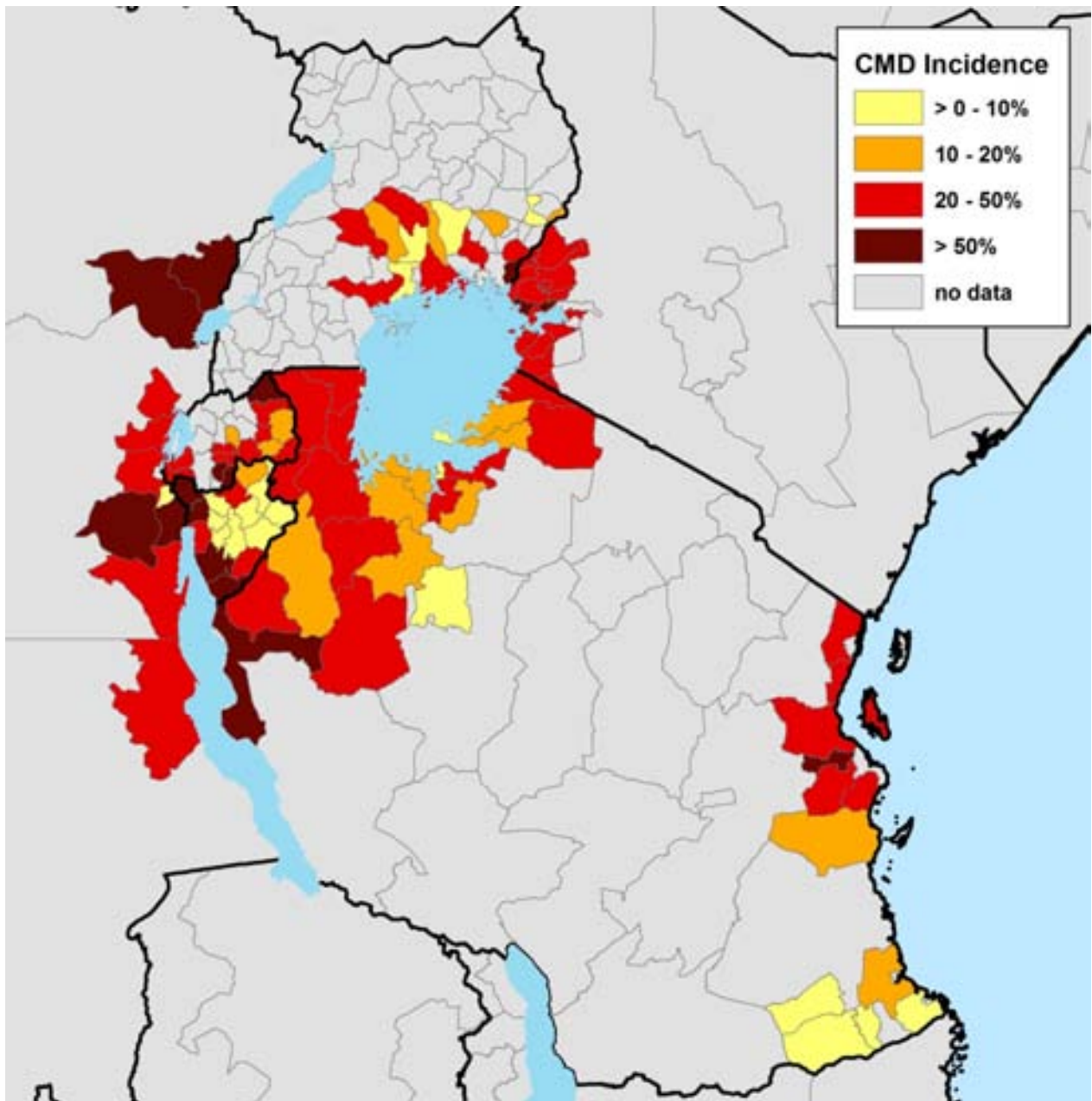
Country	Districts	Sites	Districts	Sites
	Young Fields	Young Fields	Old Fields	Old fields
Burundi	16	240	16	160
DR Congo	10	146	10	92
Kenya	15	225	15	150
Rwanda	14	-	-	-
Tanzania	36	516	36	330
Uganda	15	-	-	-
<b>Total</b>	<b>106</b>	<b>1127</b>	<b>77</b>	<b>732</b>

A spatial interpretation of the districts is given in the Global Administrative Areas Database ([www.gadm.org](http://www.gadm.org)). The names of the districts were matched to the names of administrative units in the database. This allowed the average values to be mapped for each of the district-equivalent administrative units, hereafter referred to as ‘districts’. All ‘districts’ that were not sampled are displayed in gray (no data) on the various maps. Maps were generated using ArcGIS version 9 (ESRI, Redlands, USA).

### 3. Results – Young Fields

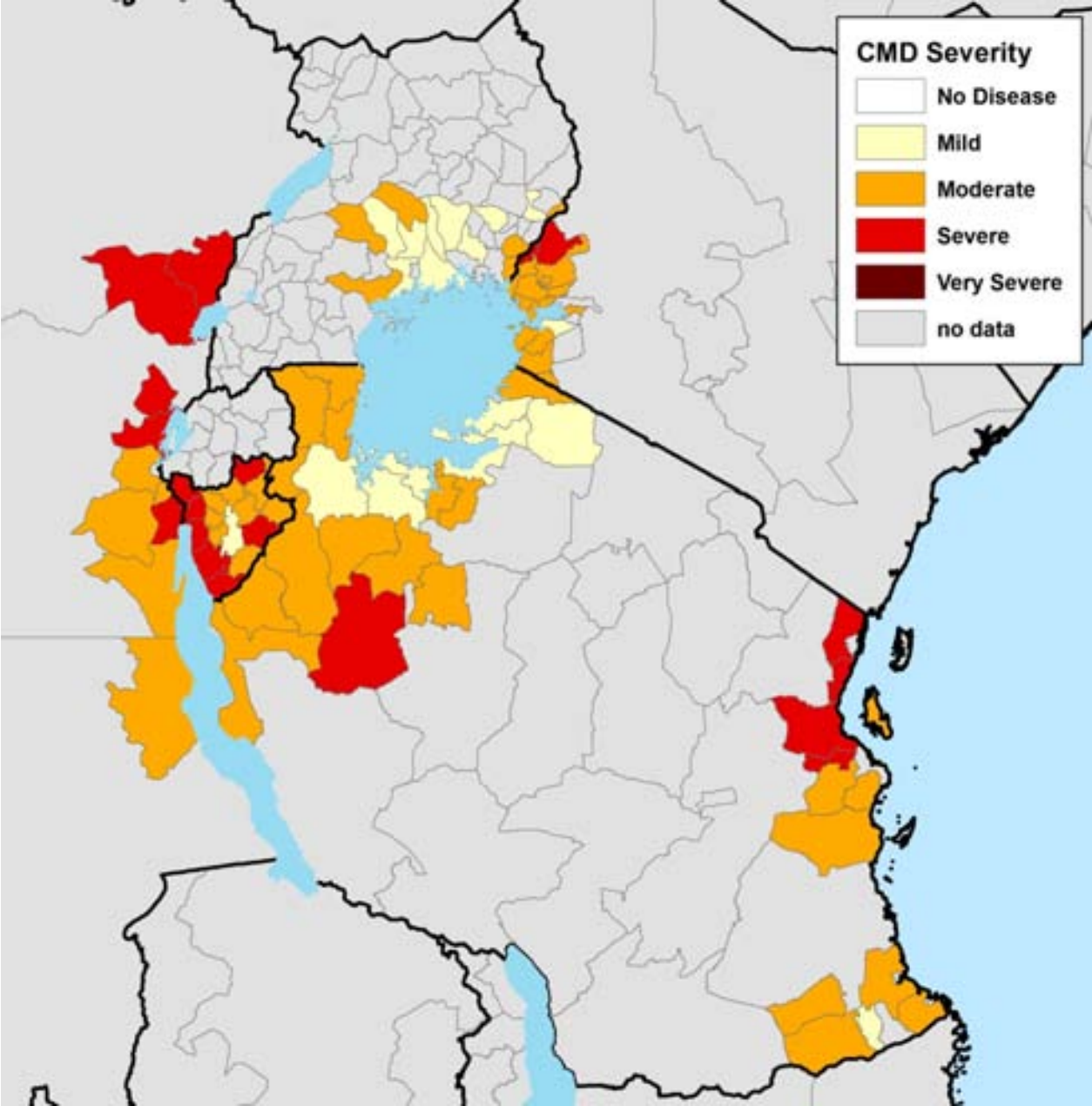
#### Map 1. CMD Incidence

CMD incidence is the proportion of plants that show symptoms of CMD. Current areas of highest incidence are the Rift Valley zone in eastern DRC, Burundi and Tanzania. These are also broadly-speaking the areas of greatest CMD severity (following map) and correspond to the zone most recently affected by the severe CMD pandemic associated with spread of the virus variant, East African cassava mosaic virus-Uganda (EACMV-UG), sometimes referred to as UgV. It is notable that incidence is currently least in Uganda, the country where improved CMD-resistant varieties are most prevalent.



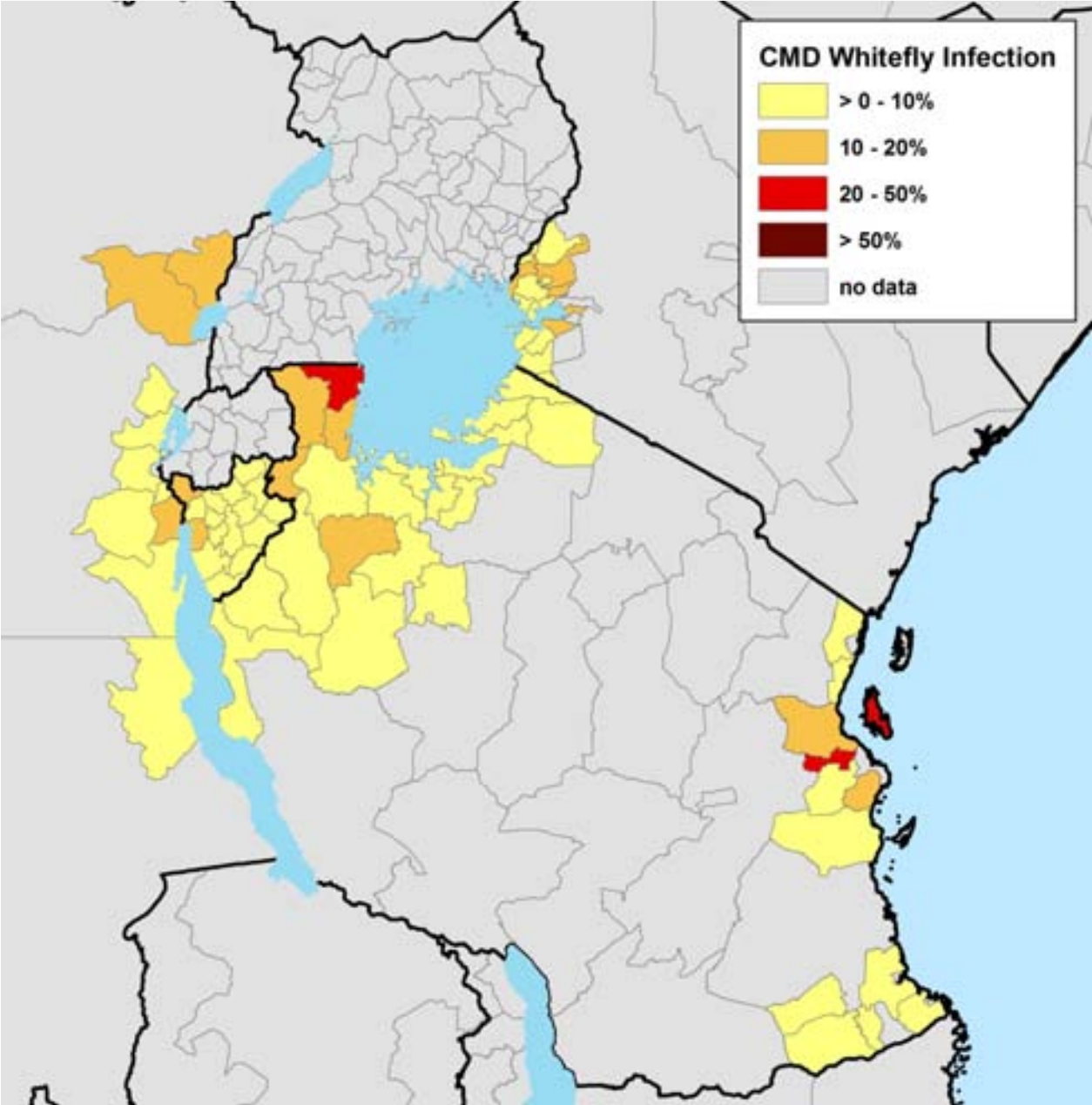
**Map 2. CMD Severity**

CMD severity is the average severity of CMD-infected plants assessed during the surveys. Symptom-free plants (with severity score '1') are not included in this calculation. The regional pattern of CMD severity was comparable with that of CMD incidence, as the zone where disease was most severe was the recently pandemic-affected Rift Valley region of Eastern DRC and Burundi. The most severely affected part of north-western Tanzania (Tabora) is notably at the current 'front' of the pandemic. Parts of western Kenya and northern coastal Tanzania were also severely affected, although by contrast, mild CMD symptoms predominated in most of Uganda and the Lake Zone area of north-western Tanzania.



**Map 3. CMD Whitefly Infection**

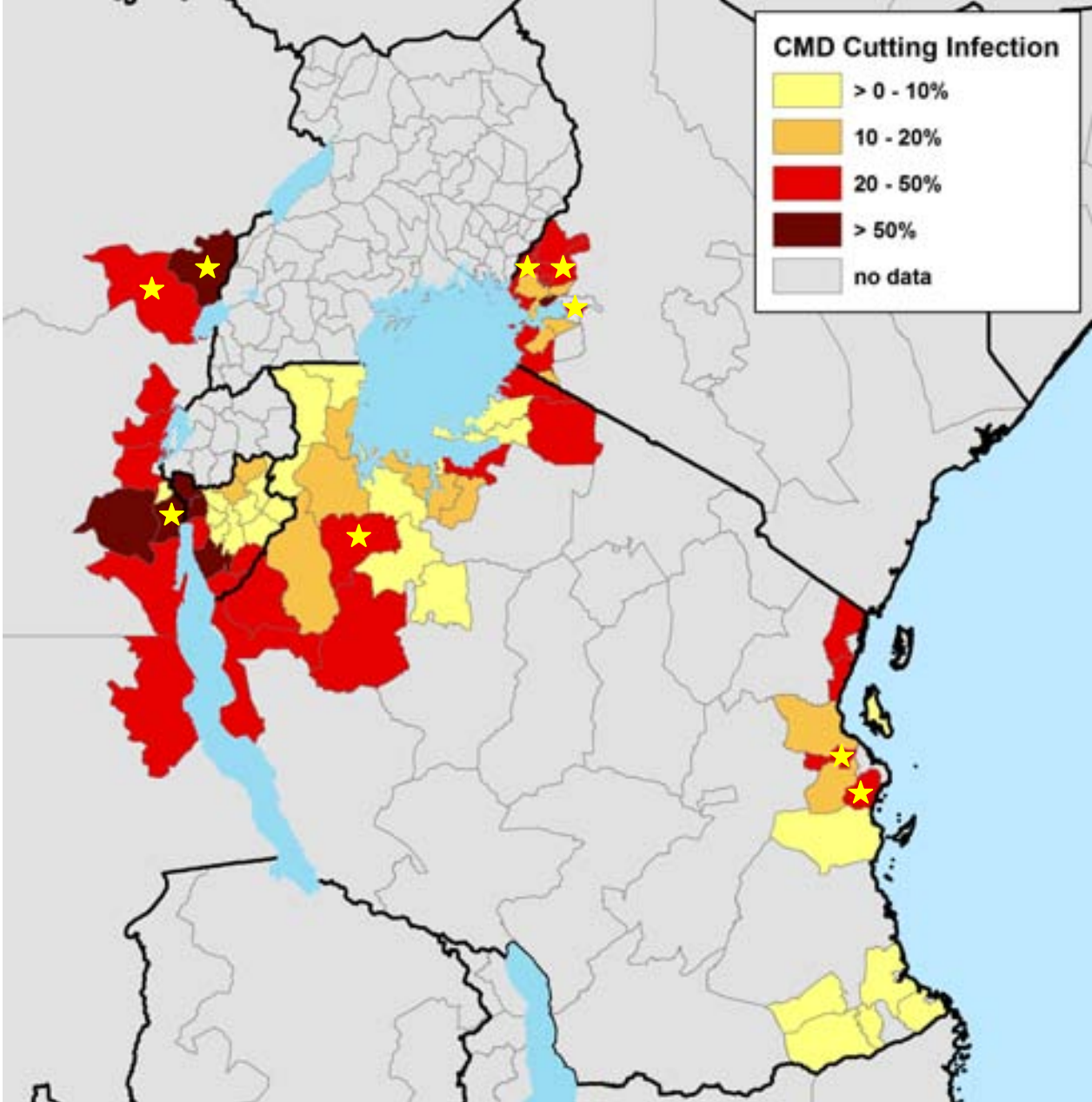
CMD whitefly infection is the percentage of plants that have current-season, whitefly-borne CMD infections. These are new infections, that contrast with the cutting-borne infections (following map) that are derived from the infection of the parent plant from which the stem cutting was taken. High levels of whitefly infection are an indicator of CMD epidemic conditions. In these surveys, highest levels were recorded in three parts of Tanzania: the far north-west, Zanzibar and Kibaha District near to Dar es Salaam on the coast. The generally moderate to low levels of whitefly infection suggest that in 2009 there was no major new spread of the CMD pandemic.





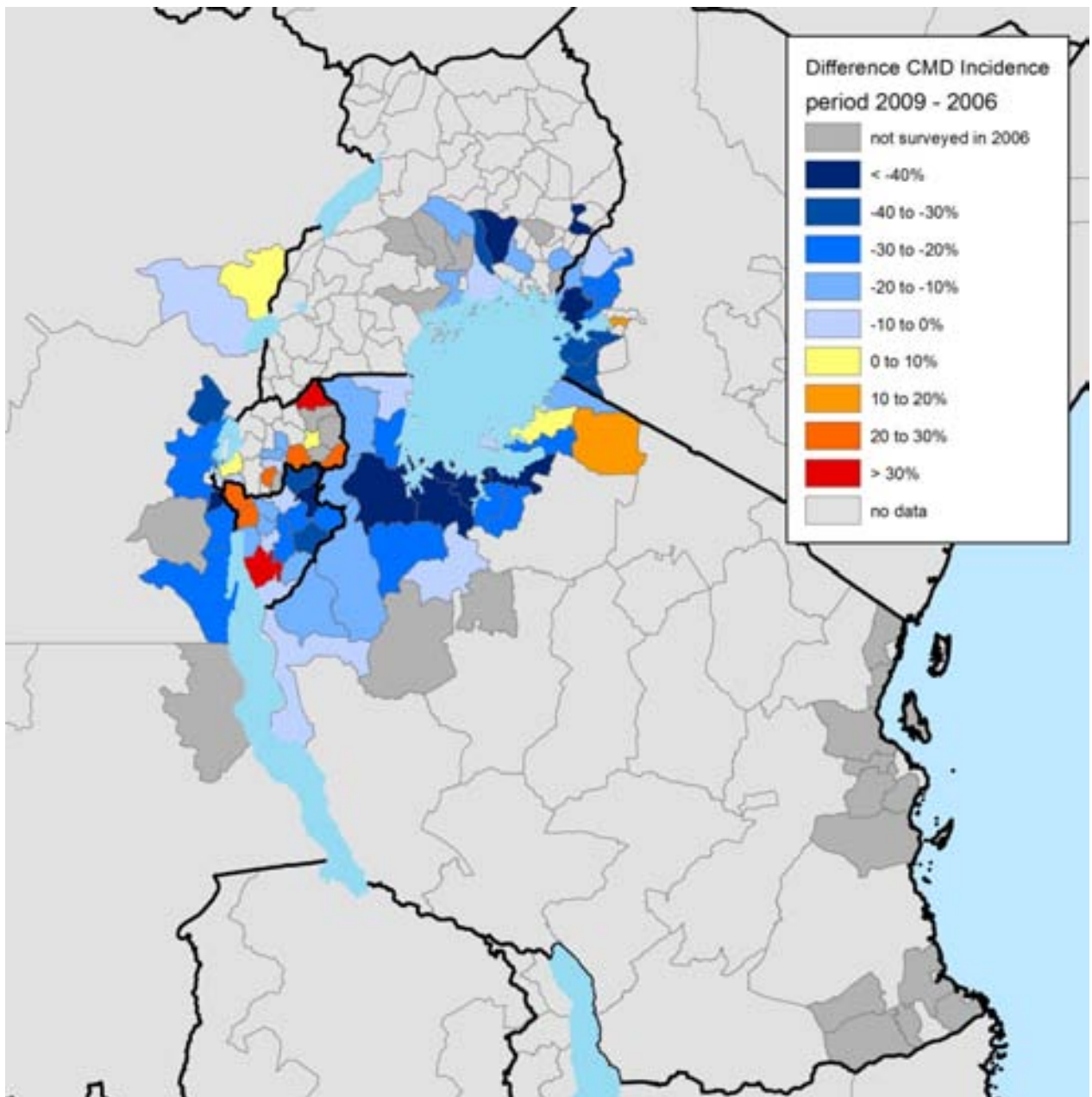
**Map 4. CMD Cutting Infection**

CMD cutting infection is the percentage of plants infected via planting material derived from infected mother plants. There was a close correspondence between cutting infection and total CMD incidence since levels of whitefly infection (the other component of total CMD incidence) were generally low. Infection rates are greatest in 'districts' that have high levels of BOTH cutting and whitefly infection. These were: Beni, Lubero and Uvira in DRC, Bukombe, Kibaha and Mkuranga in Tanzania and Busia, Kakamega and Nyando in Kenya (marked with yellow stars).



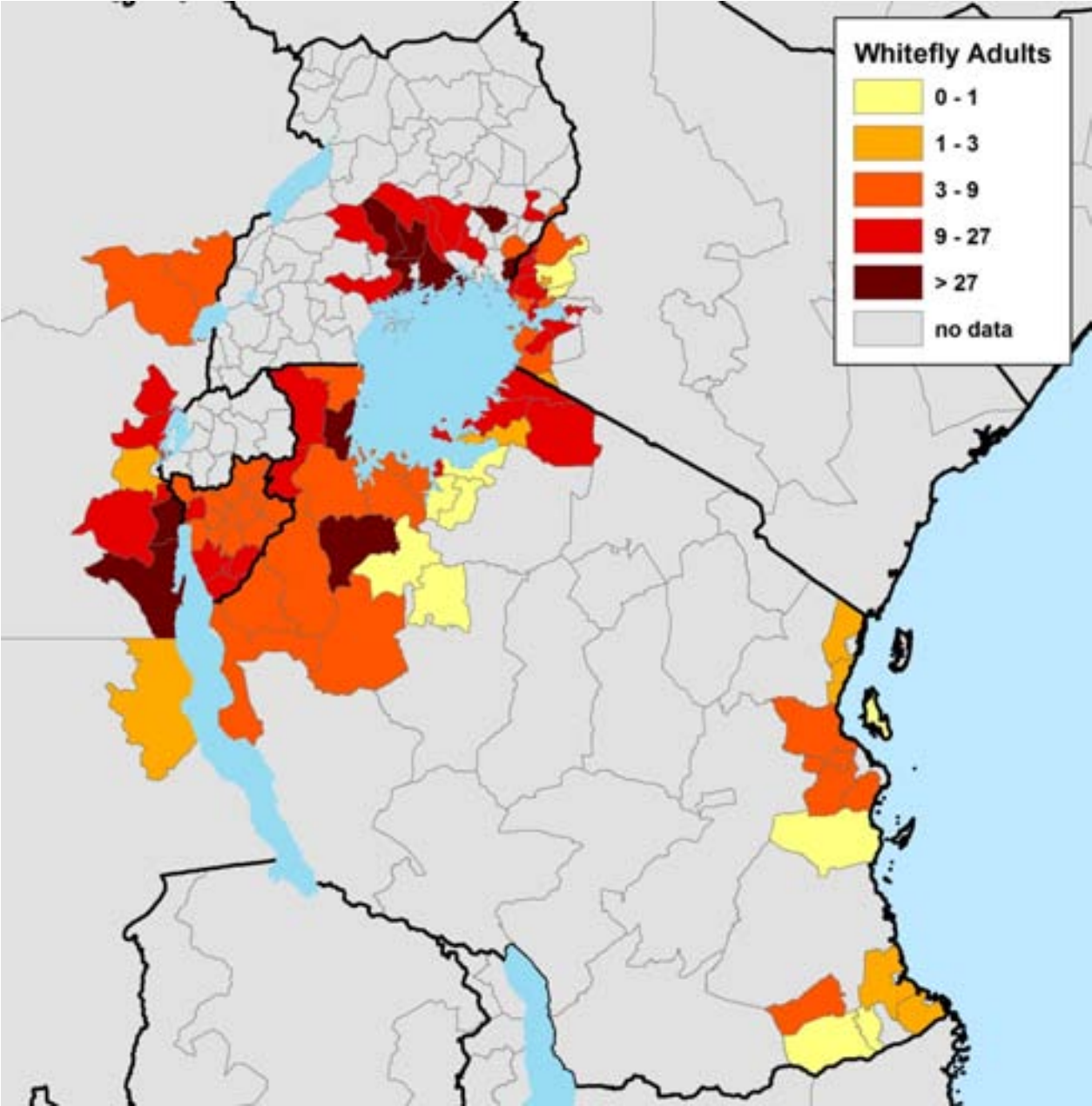
### Map 5. Change in cassava virus disease incidence: 2006-2009

Change in virus disease incidence over time in East and Central Africa can be determined by comparing incidences recorded in the 2009 GLCI surveys with incidences recorded during a previously implemented similar project – the Crop Crisis Control (C3P) Project. Methodologies were slightly different for the survey sets, but incidence was recorded in the same way for the same number of plants in each field assessed (30 plants) in both C3P and GLCI surveys. The datasets are therefore broadly comparable. In Map 5, change in CMD incidence was calculated by subtracting the incidence in a ‘district’ in 2006 from the incidence recorded in 2009. Significantly, ‘districts’ where CMD incidence was lower in 2009 were much more numerous than those where there was an increase. Rwanda, south-western Burundi and parts of Mara Region in Tanzania were the only areas where there were widespread increases in CMD incidence. Change in CBSD incidence is not presented, as incidence of this disease was negligible in 2006. Virtually all current incidence has arisen from infection subsequent to 2006.



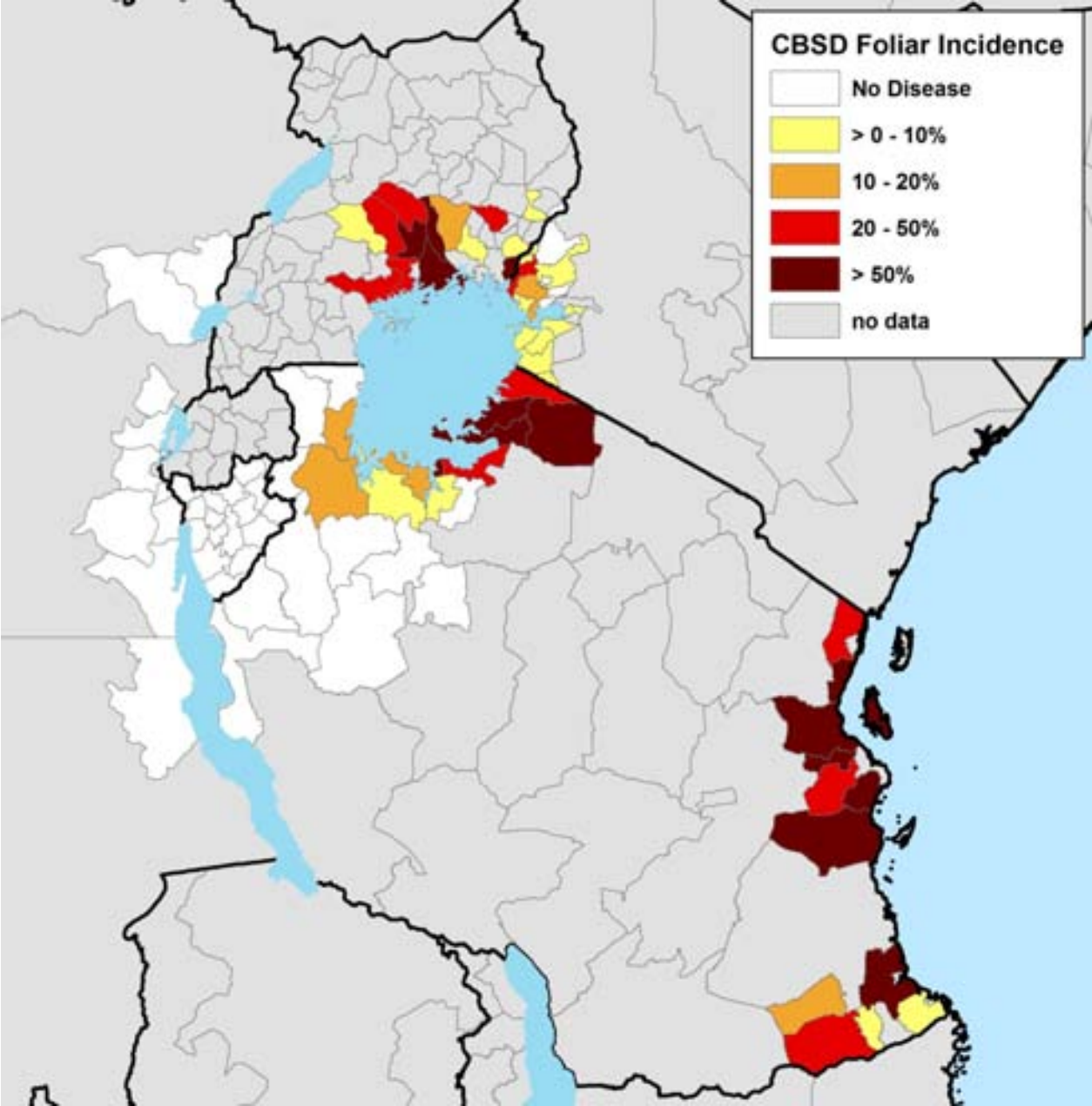
**Map 6. Whitefly Adults**

Whitefly adults is the average number of *Bemisia tabaci* adult whiteflies on the top five leaves of surveyed cassava plants. Abundance was highest in south-central Uganda, eastern DRC and parts of north-western Tanzania. In Tanzania, eastern DRC and, to a lesser extent, south and eastern Burundi, high whitefly abundances corresponded with high levels of CMD. Although whiteflies were very abundant in south-central Uganda, CMD incidence was low, which is a consequence of the fact that the majority of farmers there are growing CMD-resistant varieties.



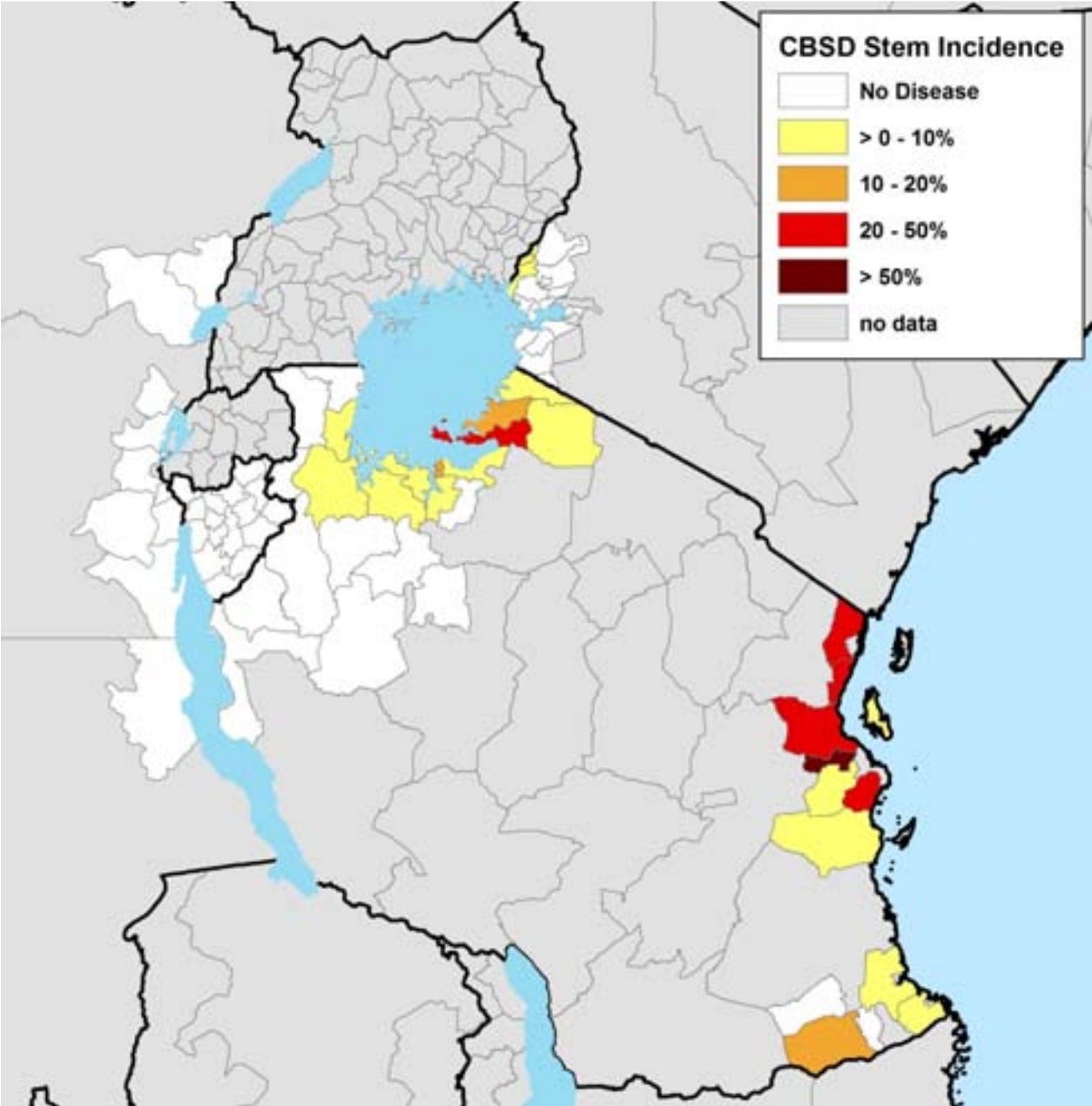
**Map 7. CBSD Foliar Incidence**

CBSD foliar incidence is the percentage of plants expressing symptoms of CBSD in the leaves. Significantly, no leaf symptoms of CBSD were observed in eastern DRC, Burundi or the westernmost part of Tanzania. In Uganda, incidence was greatest in the central southern region, around the District of Mukono, the location of the first observation of the new outbreak in Uganda (Alicai *et al* 2007). In the Great Lakes region, incidence was greatest in the immediate surrounds of Lake Victoria. In Kenya, incidence was highest along the Uganda border, and in Tanzania, in Mara Region, to the east of Lake Victoria. Overall, CBSD foliar incidence was greatest in coastal Tanzania, the area from which CBSD was first reported in the 1930s.



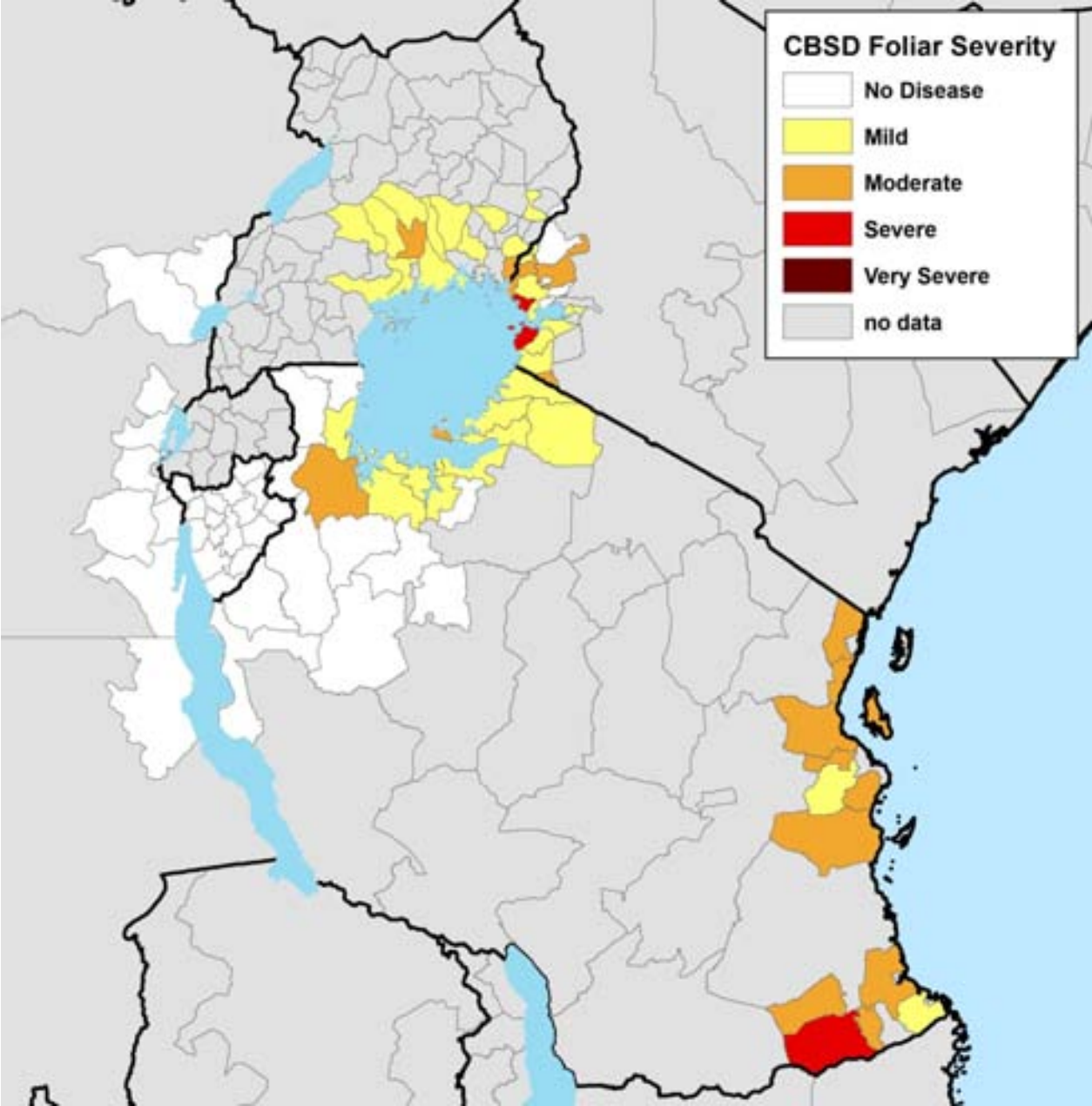
**Map 8. CBSD Stem Incidence**

CBSD stem incidence is the percentage of plants showing CBSD stem lesions. Only two zones within the Project target area had significant incidences of CBSD stem symptoms. These were the area to the east of Lake Victoria in Tanzania, and north-eastern coastal Tanzania. A general association is apparent between CBSD foliar and stem incidences, however, stem incidences were almost always lower than those of foliar symptoms. Stem symptoms were most commonly found in Kibaha District, coastal Tanzania.



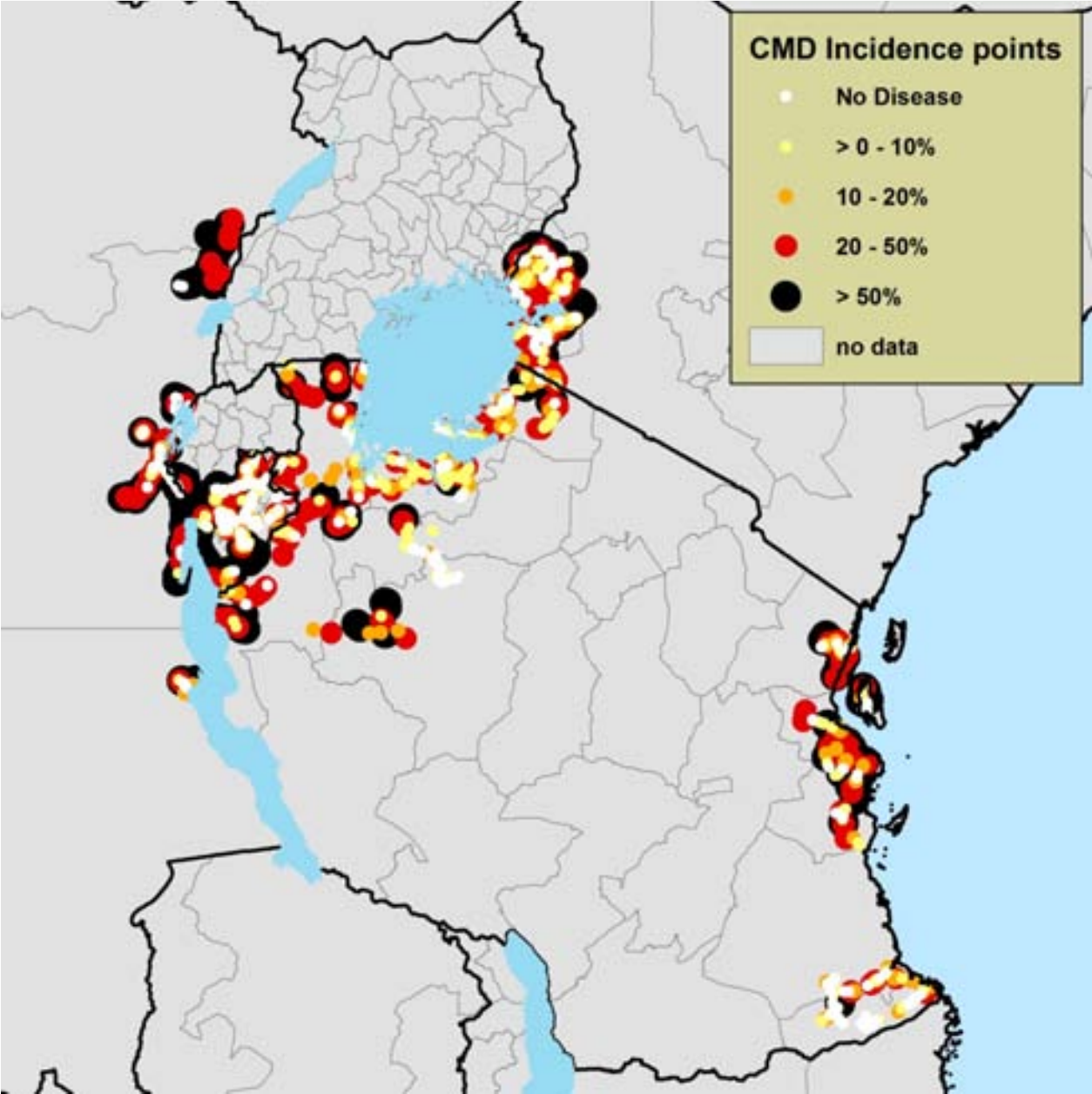
**Map 9. CBSD Foliar Severity**

CBSD foliar severity is the average severity of CBSD foliar symptoms for all plants expressing those symptoms. This severity measure does not include plants that showed no signs of CBSD foliar symptoms. In contrast to CMD, where severe foliar symptoms were widespread, in the case of CBSD, there were only a few 'districts' where symptoms were severe. These included Bondo and Suba Districts in Kenya and Masasi district in southern Tanzania. Also in contrast to the situation for CMD, there was a weak association between CBSD foliar severity and foliar incidence. There was also no clear geographical association between CBSD foliar severity and incidences of root symptoms recorded from the Old Field sites.



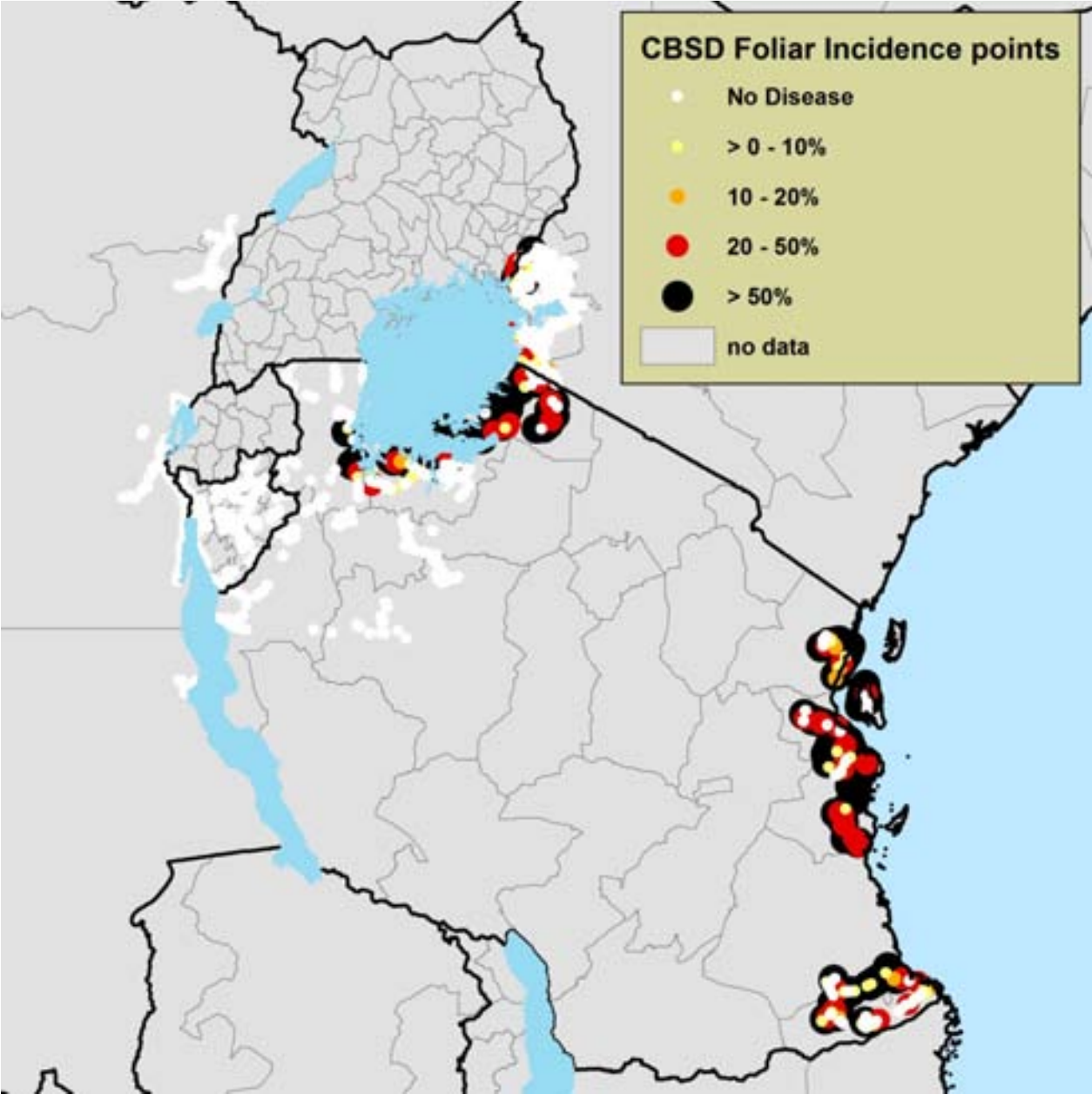
**Map 10. CMD Incidence (points)**

The point data presentation of CMD incidence illustrates the site to site variability that was recorded in most of the surveyed areas. Thus, in most of the areas where high incidences were recorded, there were also fields in which no CMD was observed. The exceptions to this are the northern part of eastern DRC where incidences were almost uniformly high. A similar effect is apparent in Tabora Region, in central-western Tanzania. Central Burundi and parts of north-western Tanzania immediately south of Lake Victoria had the opposite pattern, where almost all fields had moderate to low incidences.



**Map 11. CBSD Incidence (points)**

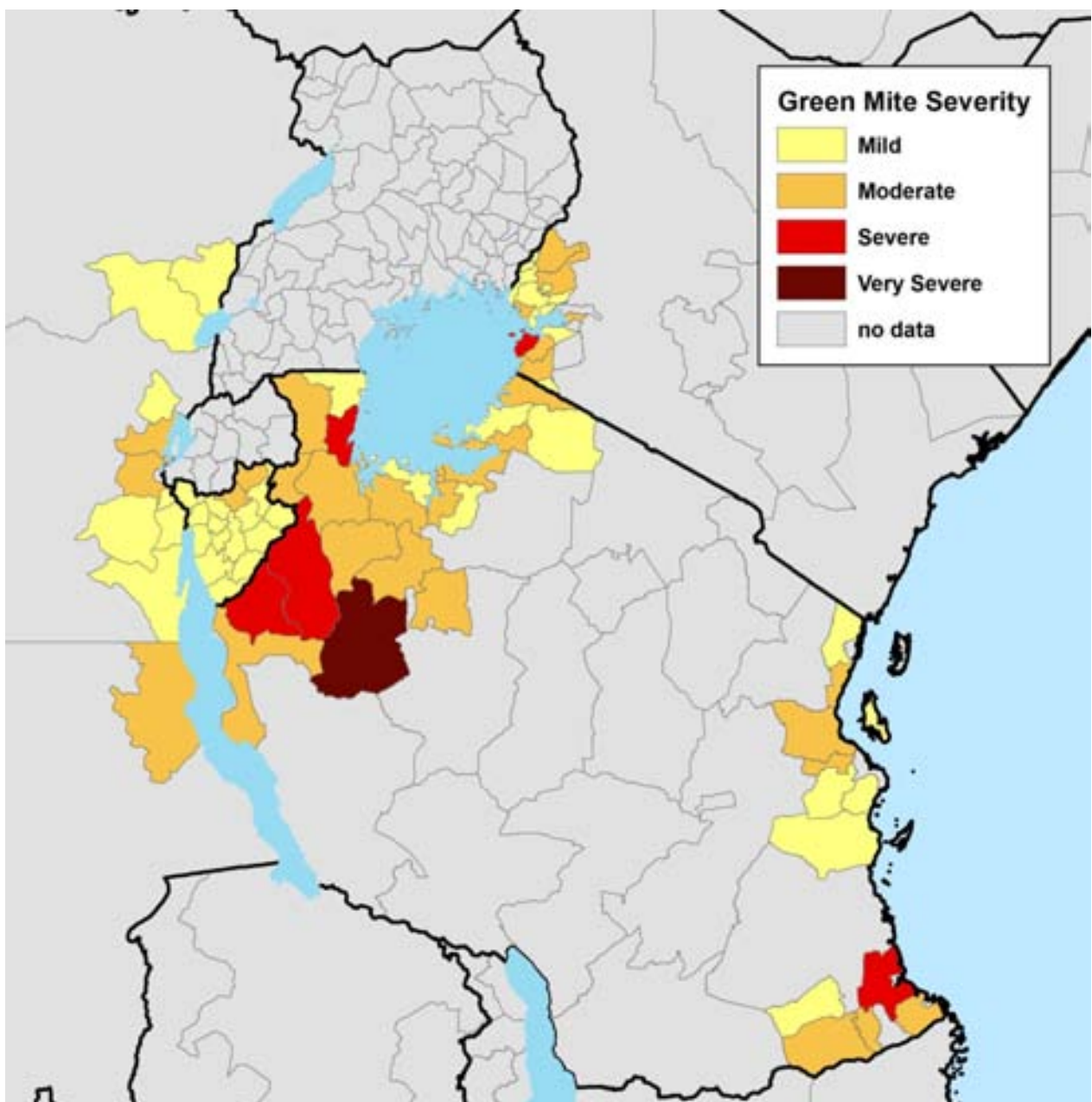
The point-based presentation of CBSD foliar incidence highlights the strong localization of CBSD foliar symptoms, even within ‘districts’ within which they occurred. In addition, there appears to be less field-to-field variability within affected areas than is observed for CMD. The ‘outbreak’ nature of CBSD in the Lake Zone in Tanzania is apparent from the localization of affected fields as well as the proximity of heavily infected areas to virtually untouched zones. This effect is also apparent in western Kenya. This contrasts strongly with ‘endemic’ coastal Tanzania, where heavily diseased sites are located virtually throughout the zone.





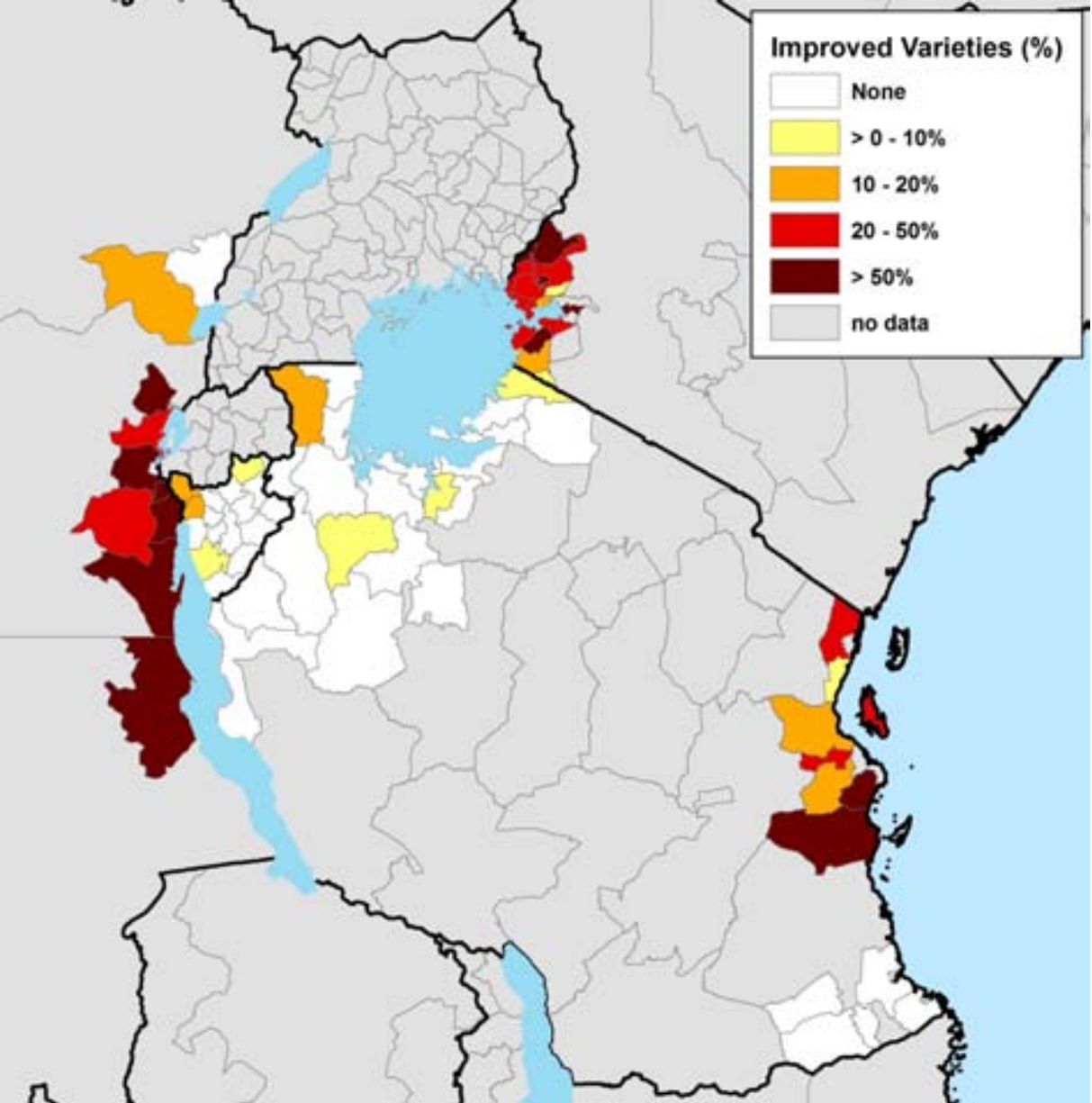
## Map 12. Cassava Green Mite Severity

Cassava green mites (CGM) – *Mononychellus tanajoa* – have been one of the most important pests of cassava following their accidental introduction to the African continent from Latin America in the 1970s. CGM were the target of a major biological control campaign in the 1990s and are now considered to be under effective control by the introduced mite predator – *Typhlodromalus aripo*. The 2009 surveys generally confirm this status, although severe or very severe symptoms were reported from Suba District in western Kenya and parts of north-western Tanzania. The very high severity reported from Urambo District may also be a consequence of the exaggeration of symptom severity scores resulting from co-occurrence with severe CMD, although *T. aripo* was found to be virtually absent from these north-western areas of Tanzania (data not shown). The relatively low incidence of *T. aripo* observed elsewhere suggests that additional biocontrol agents may be required to sustain CGM control in the near future.



### Map 13. Improved Varieties

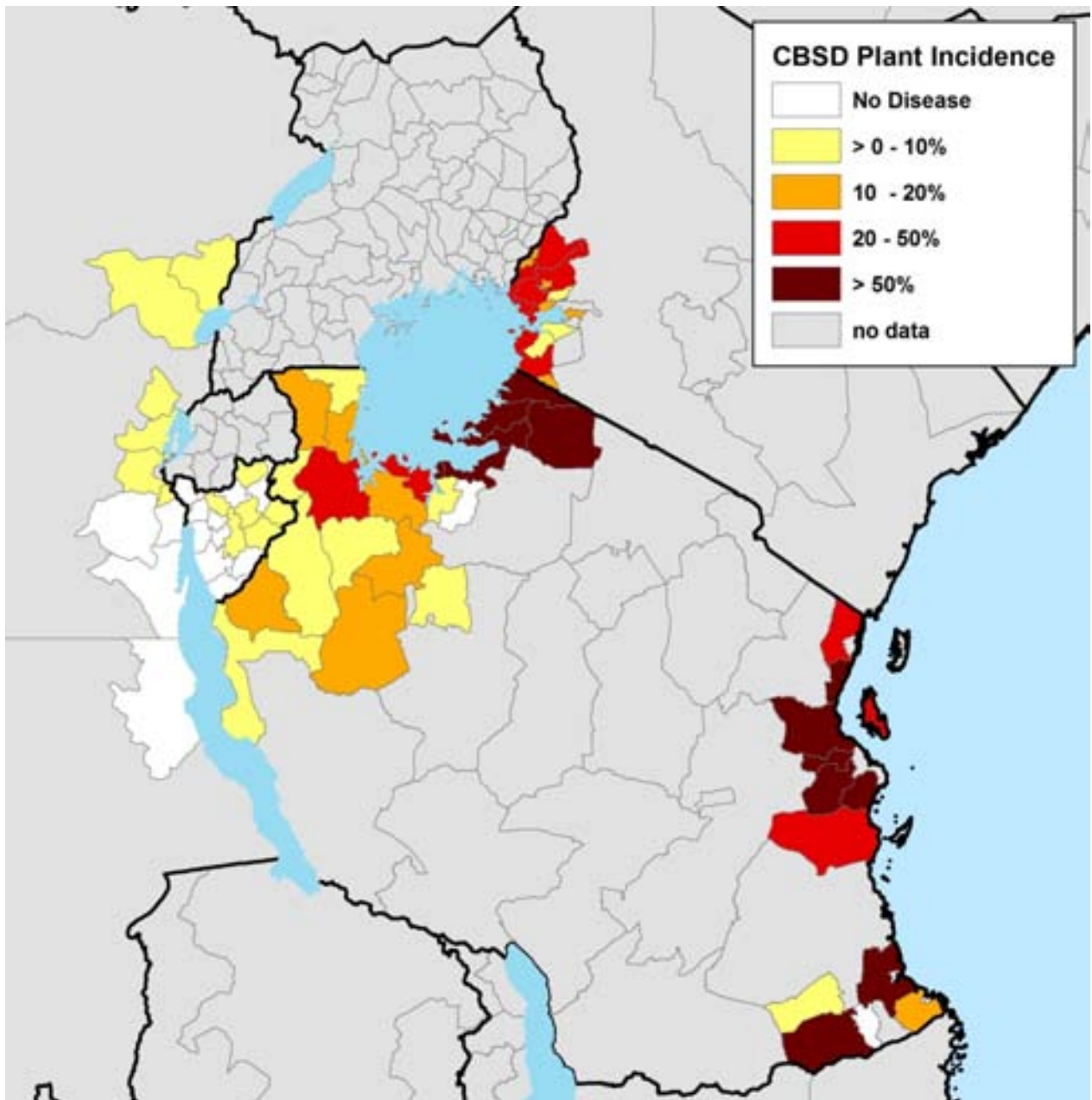
'Improved varieties' is the percentage of sites in each 'district' at which at least one improved variety was recorded in the sampled field, although the improved variety was not necessarily the sampled variety. Although only the predominant variety was sampled, all varieties being cultivated were recorded, and if any one of these was improved, that site was considered to 'have' an improved variety, and was therefore included in the 'Improved varieties' percentage calculation. The most important characteristic of improved varieties is strong resistance to CMD. It is only in coastal Tanzania that improved varieties have been selected primarily for tolerance for CBSD. Improved varieties were widespread in western Kenya, most particularly in the areas bordering Uganda. Similarly, more than half of all farm sites visited in the central and southern parts of the sampled area in DRC contained improved varieties. This pattern contrasted with the northernmost part of the surveyed area in DRC where improved varieties were less frequent. Improved varieties were relatively infrequent in Burundi and the north-western part of Tanzania. In coastal Tanzania, whilst improved varieties were completely absent from the southern coast, they were widely grown through much of the central and northern parts of the coastal strip, including Zanzibar.



## 4. Results – Old Fields

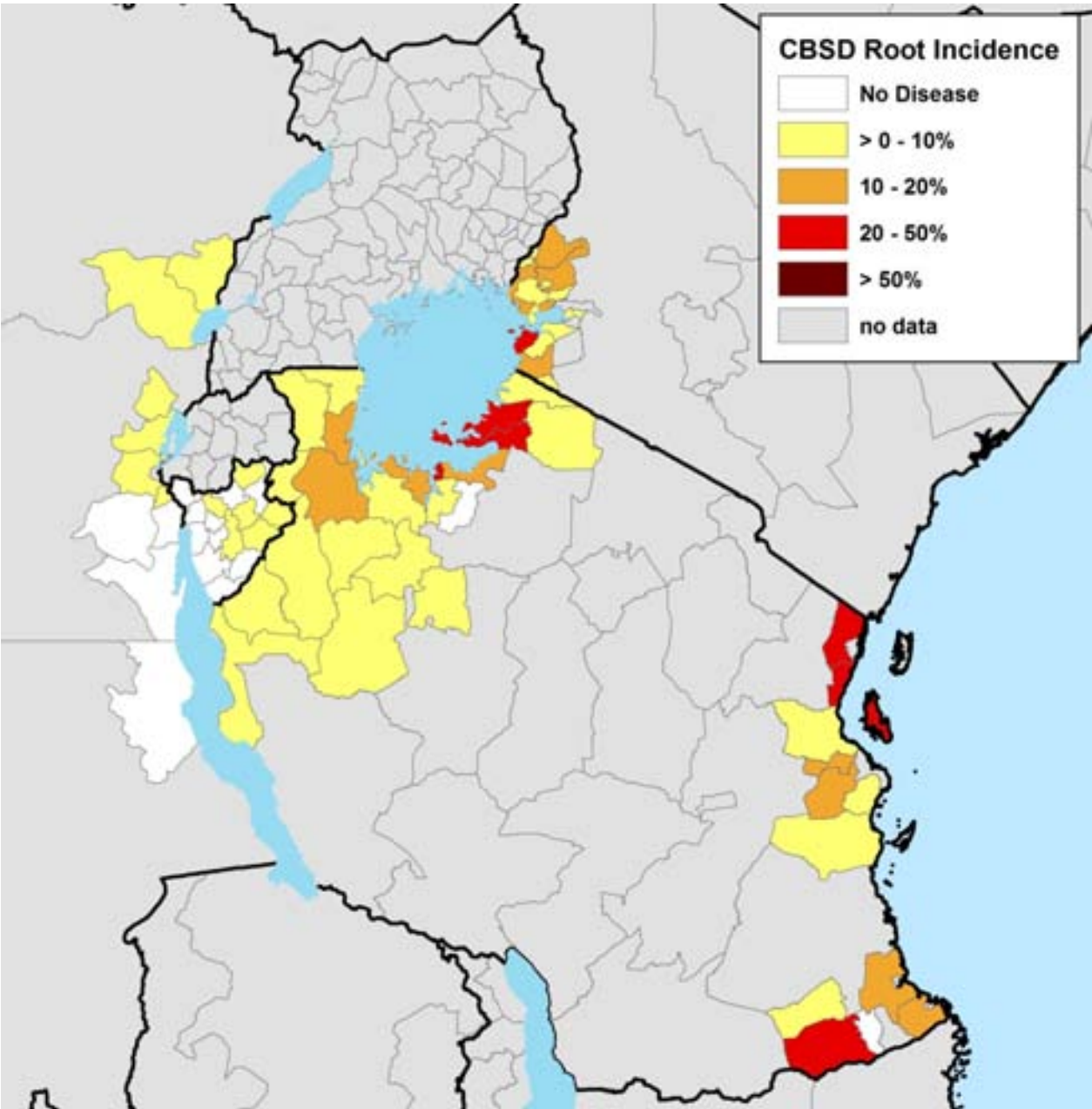
### Map 14. CBSD Plant Incidence

CBSD plant incidence is the percentage of plants in the Old Fields surveyed with CBSD symptoms of any kind (root, leaf or stem). If this map is compared with Map 7 – CMD Foliar Incidence for Young Fields – it can be seen that more ‘districts’ are affected in more countries, and that incidence levels of greater than those presented in Map 7. This is a consequence of the fact that a substantial number of plants showing no leaf symptoms had root symptoms. In spite of this, there is a good general correlation between these two data sets and the areas of highest incidence remain the eastern shores of Lake Victoria and coastal Tanzania.



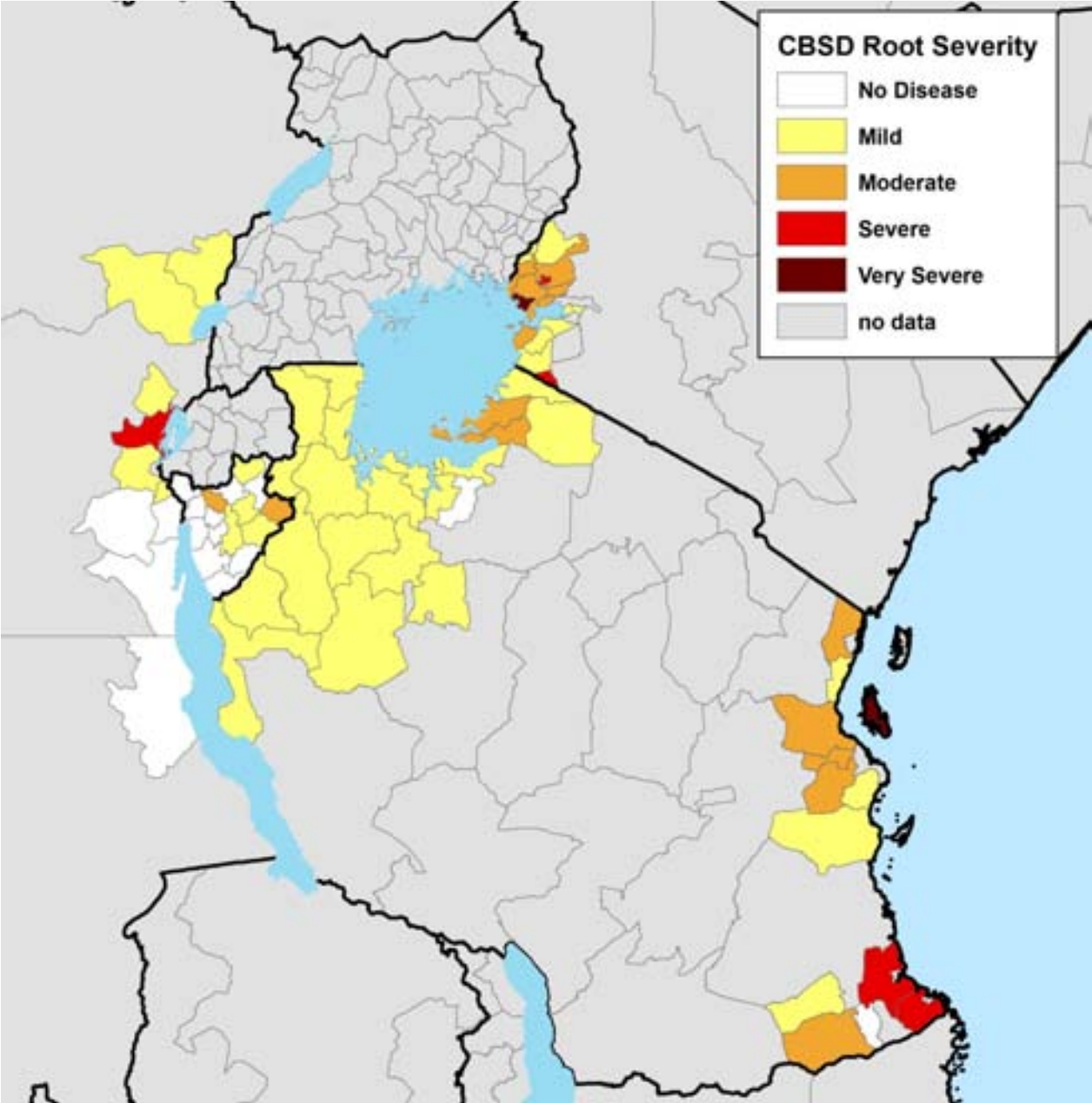
**Map 15. CBSD Root Incidence**

CBSD root incidence is the percentage of roots showing symptoms of CBSD. Each tuberous root was cut transversely five times at regular intervals along its length, and a root was considered to be infected if symptoms were present in any one of these five cuts. The most striking observation, alluded to in the commentary for Map 22, is that there were many ‘districts’ where root symptoms were seen in the absence of foliar symptoms. This was particularly noticeable in the western part of the surveyed area that included the northern part of eastern DRC, the north-eastern portion of Burundi and the far westerly sampled area in Tanzania. Highest incidences were again observed on the eastern shores of Lake Victoria and in coastal Tanzania. However, the central region of coastal Tanzania had surprisingly low root incidences. This is a result of the widespread cultivation in this zone of CBSD-tolerant varieties, such as ‘Kiroba’, that readily express foliar symptoms but rarely root symptoms.



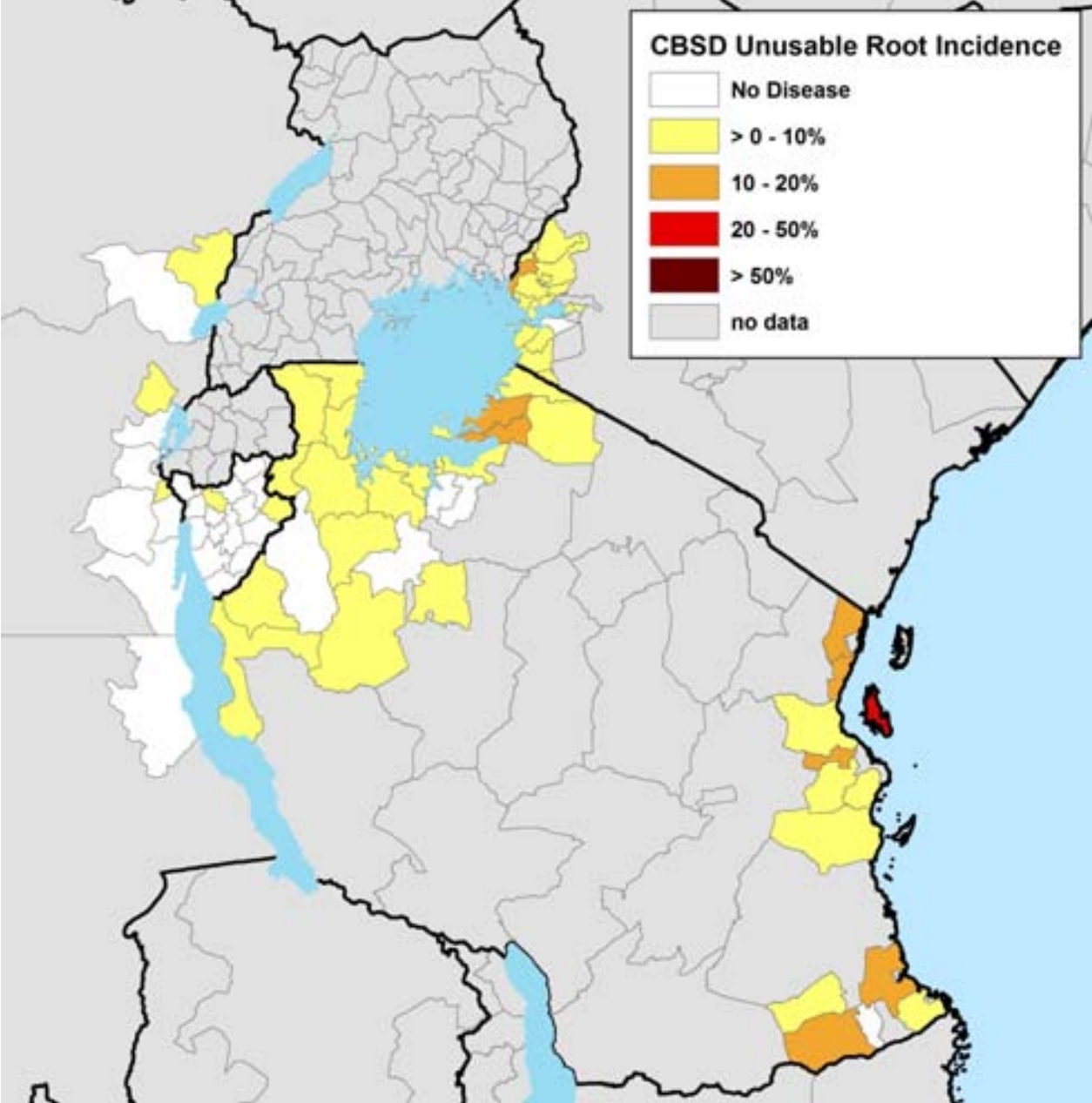
**Map 16. CBSD Root Severity**

CBSD root severity is the average severity of CBSD root symptoms. Only symptomatic portions of affected roots are included in the calculation (scores 2-5). Root severity was greatest in Zanzibar and parts of western Kenya. The apparent high severity for one 'district' in eastern DRC was obtained from a small number of plants and is therefore not as representative of the status of CBSD root severity as are the severity values obtained from western Kenya and Tanzania, where scores were obtained from large numbers of infected roots. Low severities for 'districts' in the central part of coastal Tanzania are due to the widespread cultivation of tolerant varieties.



**Map 17. CBSD Unusable Root Incidence**

The incidence of unusable roots due to CBSD is the percentage of roots that had at least one (of five) cuts with a severity score of 3 or more. Roots with this condition were considered to be unusable. The value reflects a direct loss that farmers experience due to CBSD. Only 9 'districts' were shown to have unusable root incidences of > 10%, of which all but one were in Tanzania (although data for Uganda are not available, and high foliar symptom incidences there suggest that some Ugandan districts would also fall into this category). Zanzibar was the only sampled area with an unusable root incidence greater than 20%.

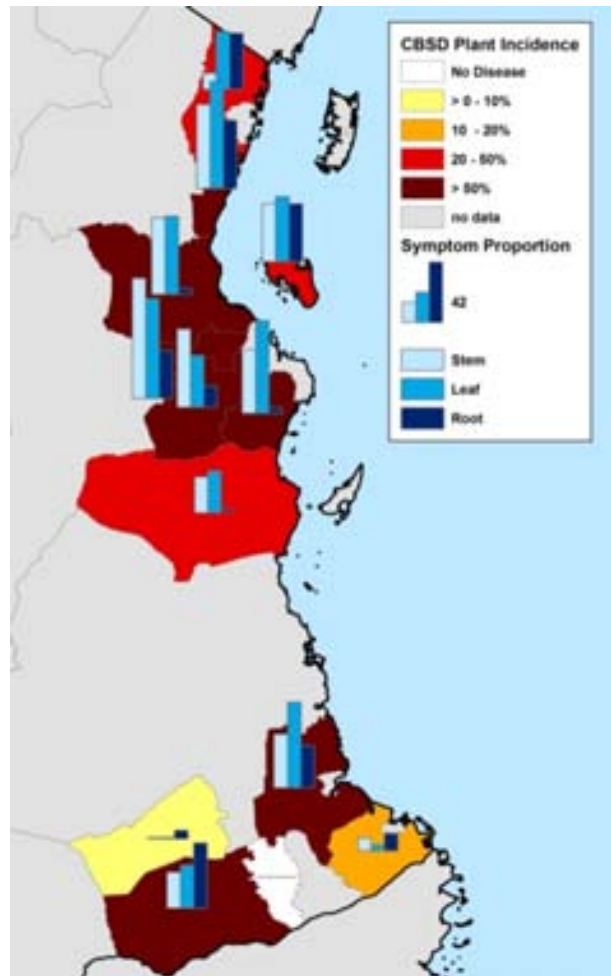


### Maps 18, 19 and 20. Proportion of CBSD symptom types

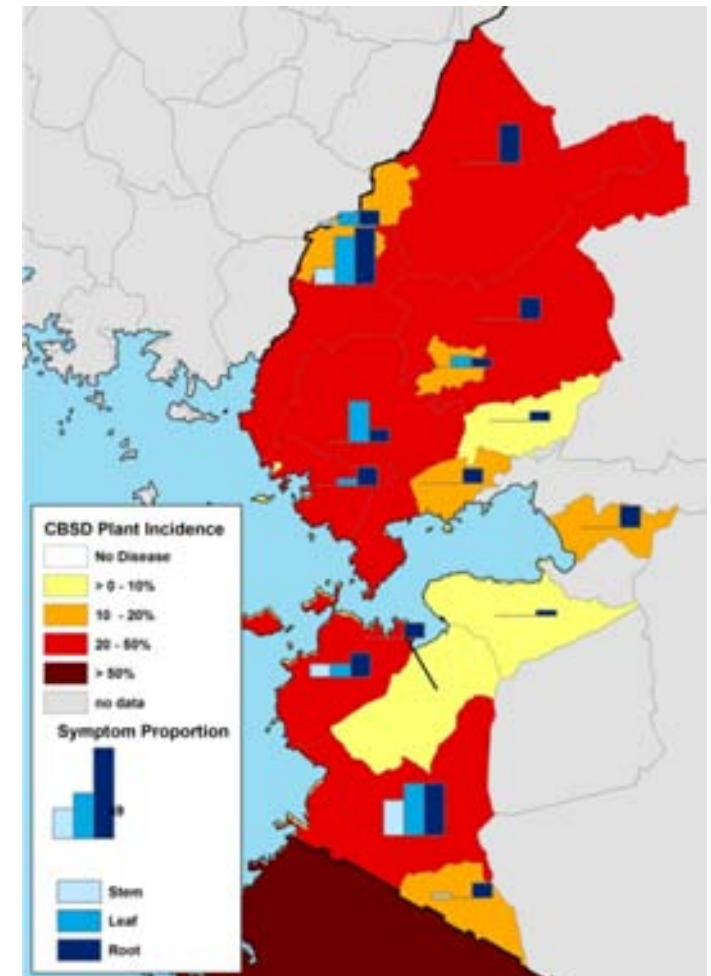
CBSD plant incidence is the percentage of plants in the old fields surveyed that have CBSD symptoms of any kind (root, leaf or stem). The size of the bar charts increases with the CBSD plant incidence in each district. Individual bars within the charts illustrate levels of each of the three main symptom types.

Of the three zones in which CBSD was most prominent (Tanzania Coast, Tanzania Lake Zone and western Kenya), Coastal Tanzania had the greatest proportion of leaf and stem symptoms. By contrast, in much of western Kenya, leaf and stem symptoms were either absent, or present at very low incidences. The pattern observed in the Lake Zone of Tanzania was closer to that of coastal Tanzania. However, there were notable differences between the districts with highest overall CBSD plant incidences, and those with low plant incidences. Where overall plant incidence was high, leaf and stem symptoms were most prominent, whilst in districts with low overall plant incidences, root symptoms predominated, and in many cases were the only symptom of CBSD. Root symptoms recorded in parts of Burundi and eastern DRC will need to be verified as CBSD, since none of the fields where these were recorded showed any signs of foliar symptoms of CBSD.

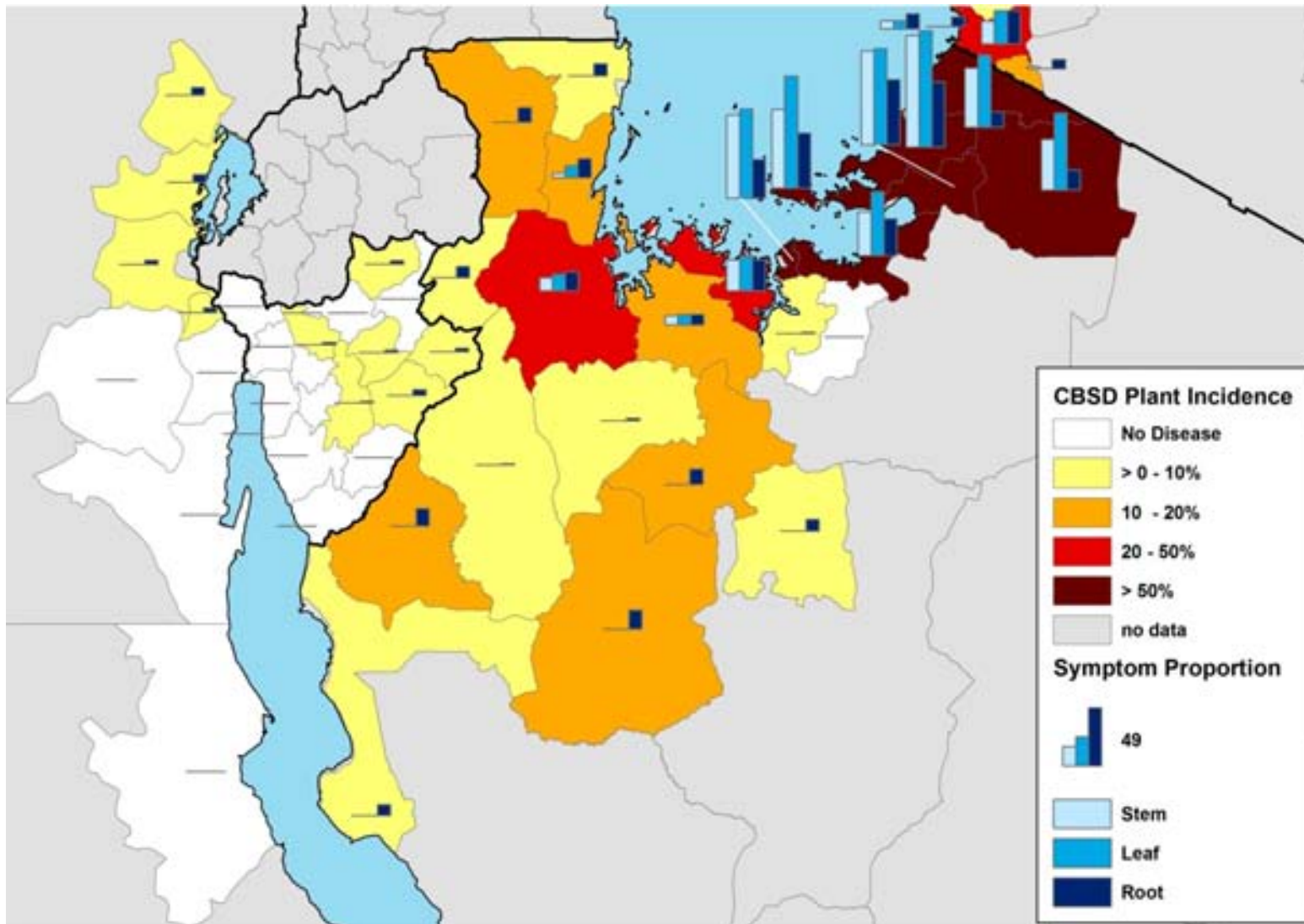
**Coastal Tanzania**



**Western Kenya**



### The southern Great Lakes region

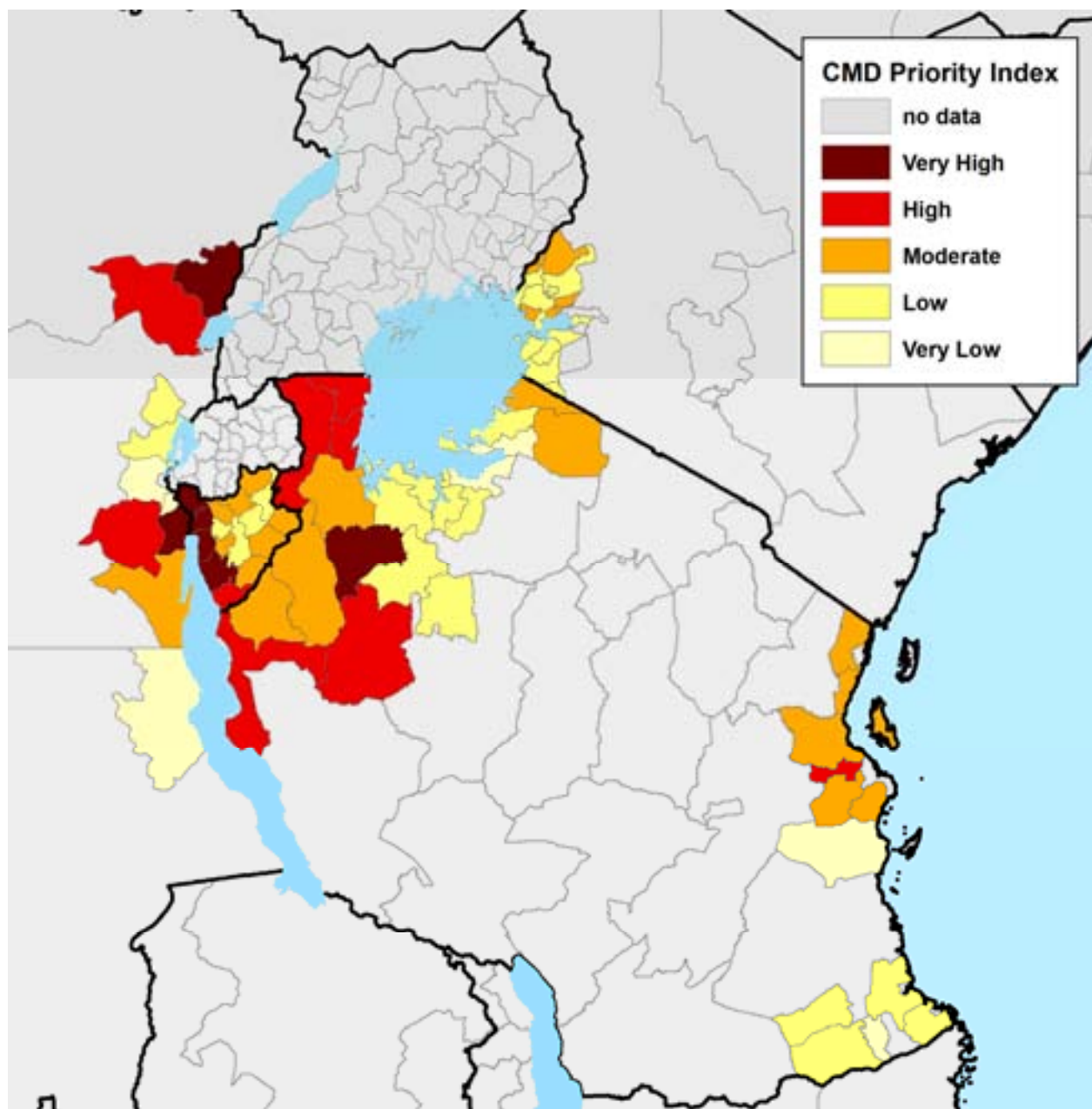




## 5. Results – Disease Change and Priority Maps

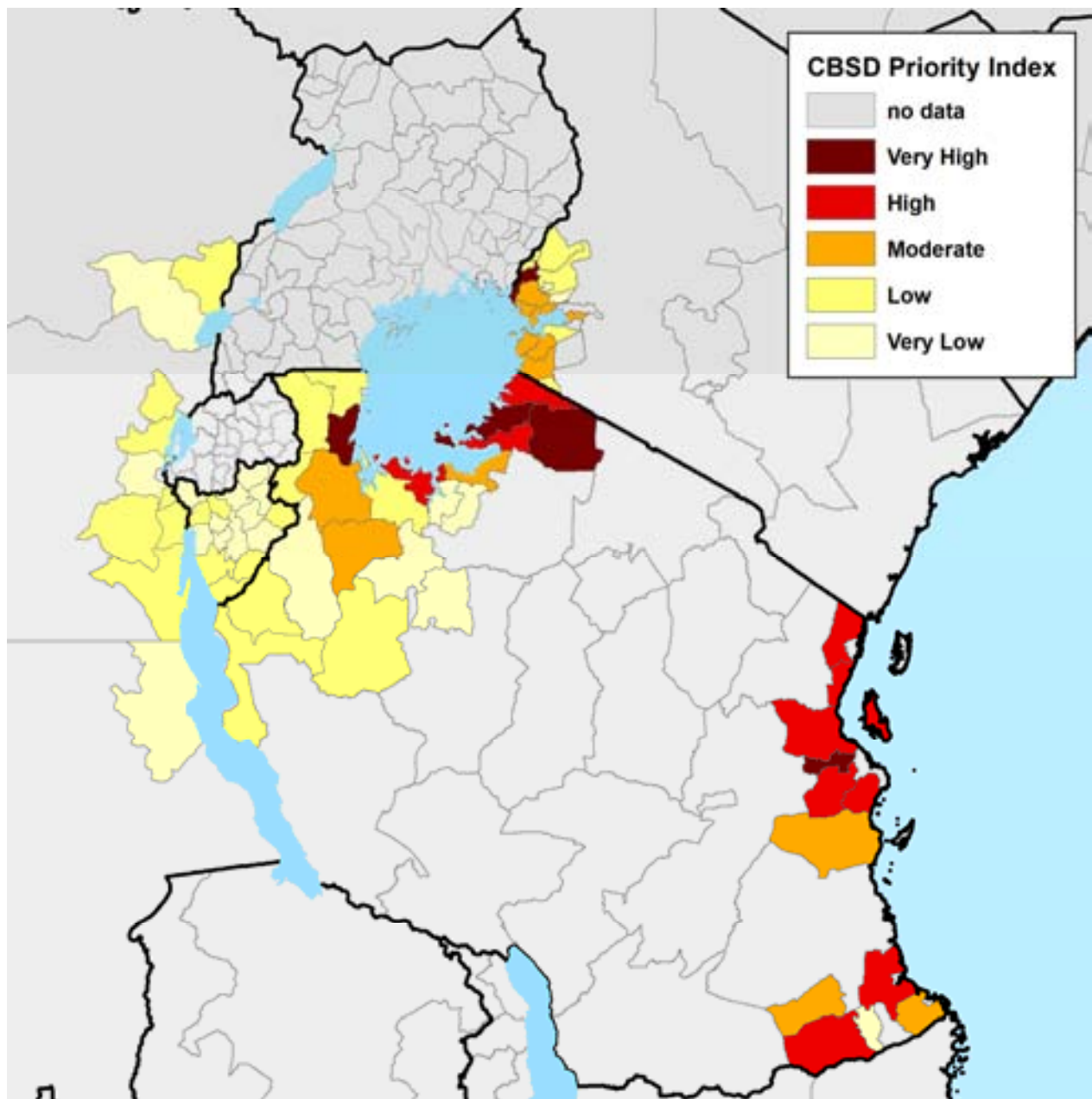
### Map 21. CMD Priority Index

CMD survey data can be combined with variety information to determine which ‘districts’ are more severely affected and less well addressed by intervention programmes, and conversely, which ‘districts’ are relatively less affected and better supported by the outputs of intervention programmes. A CMD priority index was developed, which combined: CMD incidence, CMD severity, whitefly abundance, CMD infection type (whitefly vs. cutting-borne) and the availability in farmers’ fields of CMD-resistant varieties. These components were combined, with equal weighting, to provide an overall CMD priority index, which has a maximum value of 1 – equal to the highest priority – and a minimum value of 0 – equal to the lowest priority. Highest priority zones comprised north-western Tanzania, parts of eastern DRC, and the Lake Tanganyika shoreline in Burundi. The southern part of eastern DRC and western Kenya were shown to be low priority primarily since both had a high proportion of farmers that were growing improved CMD-resistant varieties.



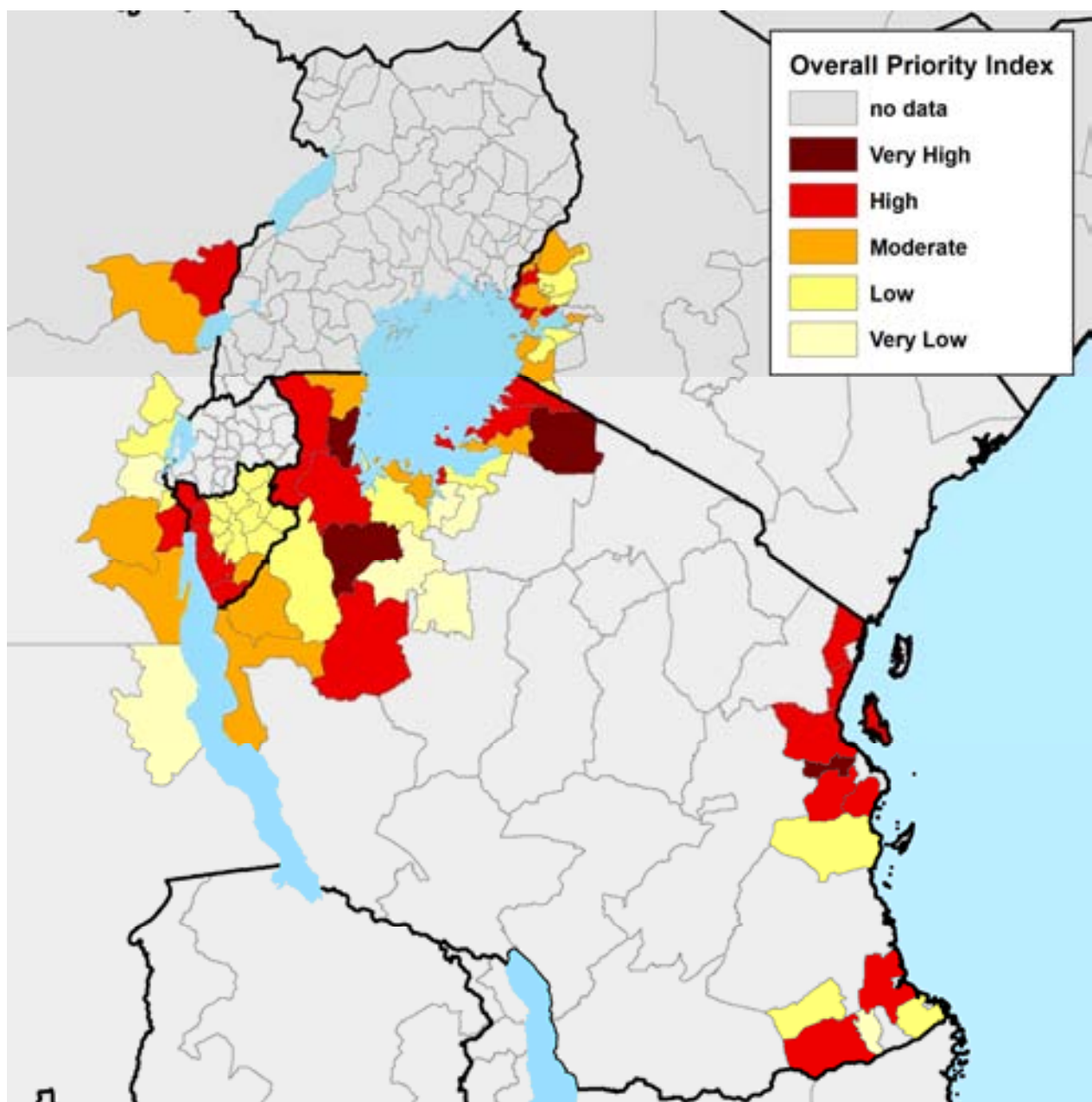
## Map 22. CBSD Priority Index

The CBSD Priority Index was compiled in the same way as the CMD Index described previously, although in this case, only three variables were combined: CBSD leaf incidence (from the Young Fields), CBSD unusable root incidence (from the Old Fields) and whitefly abundance. Index values ranged from 1 (highest priority) to 0 (lowest priority). Priority values were generally high in the coastal region of Tanzania, although the region with the greatest number of highest priority 'districts' was the Lake Zone. There were four 'very high priority' 'districts' in the Tanzanian part of this region, and one (Busia District) in Kenya.



### Map 23. Overall Cassava Virus Diseases Priority Index

The map of 'Overall Cassava Virus Disease Priority' was produced by combining index values for CMD and CBSD with equal weighting. The map produced is characterized (ironically perhaps!) by a mosaic pattern, as the combination of the two datasets served to dissipate the broad regional trends apparent in the maps for the individual diseases. An important consequence of this for institutions aiming to address these two diseases is that all regions need to be included in mitigation programmes. Within regions, however, there are strong differences between 'districts'. A good example of this is Burundi, where much of the centre, north and east of the country is currently low priority, whilst the Lake Tanganyika shoreline area to the east and south is high priority. Based on the data, a strengthened focus on Tanzania is merited in view of the fact that all four of the 'very high priority' 'districts', and the largest proportion of 'high priority' 'districts' were located there.



## 6. Discussion

### Background

Cassava mosaic disease (CMD) and the viruses that cause it have been extensively monitored through East and Central Africa since the outbreak of the severe CMD pandemic was first noted from Uganda in the early 1990s. Since that time, the expansion of the pandemic has been systematically documented as it has grown to affect more than 2 million square kilometers of the important cassava-growing regions of 12 countries of East and Central Africa (Legg et al., 2006). In response, a series of mitigation projects have been implemented to control the worst impacts of the disease, and the scale of these programmes has gradually increased in line with the ever increasing magnitude of the pandemic. The GLCI Project, with its focus on six countries in East and Central Africa, is the largest such initiative to date, and has played a key role in sustaining cassava disease monitoring and management efforts from 2007 through to the present day (2010). The disease monitoring work implemented under GLCI has had two important novel features. Firstly, it has provided the first regional-level assessment of cassava brown streak disease (CBSD), and secondly, it has facilitated the first detailed and extensive examination of the relationship between the different symptoms that are a feature of CBSD. The first series of surveys were implemented between May and September 2009 by teams of National Research System (NARS) scientists in each of the target countries, supported by IITA. NARS researchers are playing the lead role in the detailed analysis of new data obtained from these surveys for CBSD. Three draft publications have been produced, as follows:

- i) S. Jeremiah *et al.* The influence of environmental factors on the dynamics of cassava brown streak disease in East Africa
- ii) H. Obiero *et al.* Spatial relationships between factors associated with the emerging epidemic of cassava brown streak disease in western Kenya
- iii) I.Ndyetabula *et al.* Analysis of interactions between cassava brown streak disease symptom types facilitates the determination of varietal responses and yield losses

These science-oriented studies will be published in scientific journals in due course. The current report, by contrast, provides a broader more general assessment of the findings of the surveys, which should be more accessible to wide range of stakeholders with an interest in cassava and its pest/disease constraints. We have used a map-based approach to summarizing some of the key data variables recorded during the surveys. As well as providing a guide for control interventions implemented through other components of the GLCI Project, these data also serve as a regional baseline for cassava diseases against which future changes can be measured, and the success or otherwise of project activities gauged. Country-level maps have also been produced. These will be presented through country reports.

### Cassava mosaic disease (CMD)

CMD incidences were moderate to high in most of the surveyed districts throughout the Project zone. It was evident that CMD remains an important disease, and together with CBSD, represents the main constraint to the production of cassava in East and Central Africa. Patterns of incidence in the Great Lakes zone were not greatly different from those recorded during earlier surveys

implemented under the Crop Crisis Control (C3P) Project, although overall, incidence levels were significantly lower in most areas. The general pattern was of greatest incidence and severity in the areas most recently affected by the severe CMD pandemic (eastern DRC, south-eastern Burundi, Lake Tanganyika shore area of Tanzania) and lower incidences in Uganda, where control activities have been running longest. It was notable, however, that incidences in parts of the Lake Zone of Tanzania and central and northern Burundi were relatively low, and significantly lower than those recorded in previous surveys (Map 5). Since CMD-resistant varieties were infrequent in these areas, the most likely cause for this seems to be the application by farmers of phytosanitary measures (primarily the identification and selection of CMD-free planting material), coupled with a general reduction in inoculum pressure. CMD incidences were moderate in coastal Tanzania, but notably lower in the south than in the north, most likely in view of the contrasting environmental conditions: southern Tanzania has a long dry season, making it less favourable for whitefly population build-up. Moderate to high levels of both whitefly infection and cutting infection provided an indication of epidemic conditions, and districts identified in this way were present in eastern DRC, western Kenya and the Lake Zone of Tanzania. DRC's Uvira District and Tanzania's Bukombe District more-or-less correspond with the pandemic 'front' zones in each of those two countries. In both instances, severe CMD is spreading southwards over time. It is significant, however, that the speed of spread in both of these areas has not been great. In DRC, dissemination programmes of CMD-resistant varieties have been very effective. In districts immediately to the south of Uvira District, more than half of all farmers' fields have CMD-resistant germplasm as the predominant variety. Since infected cassava (and not alternative host plant species) is the only really important source of CMGs for the spread of CMD, either through planting material propagation or vector transmission, it seems clear that large incidences of CMD-resistant material in areas ahead of the CMD pandemic 'front' will slow the speed of spread and reduce the impact of the disease as it does spread. CMD-resistant varieties were infrequent in Bukombe and districts to the south. Cassava cultivation becomes increasingly sparse, however, when moving from the Lake Zone to central Tanzania. Under such circumstances, the agro-ecological environment will provide a natural barrier to rapid spread.

Sustained high populations of *Bemisia tabaci* whiteflies in central southern Uganda and western Kenya, as well as towards the pandemic front in eastern DRC and Tanzania, provide an important reminder that CMD remains a threat throughout the CMD pandemic-affected zone, even in areas first affected almost two decades ago. Additionally, although coastal Tanzania has in general been less impacted by CMD than the pandemic-affected zone around the Great Lakes, Kibaha District was notable in having high incidences of both whitefly and cutting infection. This suggests that continued close monitoring of the situation is necessary, and that increased levels of CMD-resistance must be incorporated into new germplasm targeted for introduction in this region.

### **Cassava brown streak disease (CBSD)**

Surveys confirmed that coastal Tanzania remains the region most affected by CBSD. Important additional hot-spots were apparent, however, from the new outbreak zone in the Great Lakes region. These included the eastern shores of Lake Victoria in Tanzania, the Uganda/Kenya border area – close to Lake Victoria – and central southern Uganda. CBSD root incidences were greatest in areas in which leaf symptoms were prevalent, but there were also significant areas in which root symptoms occurred virtually in the absence of leaf symptoms. These included parts of western Kenya, north-western Tanzania and parts of Burundi and eastern DRC. No definitive confirmation

based on diagnostic tests has yet been made for CBSV in either Burundi or eastern DRC. This fact, coupled with the absence of clear leaf symptoms, suggests that the incidences of root symptoms should be treated with caution. Incidences of unusable roots due to CBSD damage were relatively low, even in some of the 'districts' where leaf incidences were high. On average, unusable root incidences were approximately 4% in western Kenya and the Lake Zone of Tanzania, and 9% in coastal Tanzania. The highest value of unusable roots was obtained for Zanzibar, where 39% of all roots sampled fell into this category. This very high value appeared to be the consequence of the widespread cultivation of a highly susceptible, yet strongly farmer-preferred cultivar. Since tolerant cultivars are frequent throughout the coastal zone of Tanzania, it appears that farmers may prefer the quality advantages of CBSD-susceptible cultivars over the benefits of disease tolerance. This situation highlights the importance of combining virus resistance or tolerance with farmer-preferred cooking and taste characteristics. It is clear that there is no geographical association between the distributions of CBSD and improved varieties. These data therefore do not support the widely held view that the dissemination of improved varieties is the key factor driving the CBSD outbreak in the Great Lakes region. In spite of this, it is clear that any movements of planting material, of any type, from CBSD-affected to CBSD-unaffected areas, pose a risk of aiding the spread of the disease. A small number of introductions of infected material can 'seed' a much larger number of subsequent infections if conditions are suitable for the vector at the site of introduction. In this regard, there does seem to be an association between whitefly abundance and CBSD, although at this regional scale, the relationship is far too imperfect for any strong assertions to be supported. More detailed studies are currently being undertaken through the GLCI Project to identify the most important variables driving the recent CBSD outbreaks.

Although these data only provide a snapshot of the current status of cassava virus diseases in East and Central Africa, comparisons can nevertheless be readily be made with surveys conducted in the region under the auspices of other projects. Most significantly, for CBSD prior to 2005, incidence in the Great Lakes region can be considered to be close to zero (Legg and Raya, 1998). Steady increases have been recorded subsequently, culminating in incidence levels recorded in the 2009 surveys reported here of 23.7% in the Lake Zone of Tanzania and 29.3% in Uganda. These are still substantially lower than in Coastal Tanzania, where leaf incidence was 46.4%. The 2010 surveys (currently underway in GLCI countries) will provide an important indication as to whether the upward trend of CBSD in the Great Lakes will continue, or whether an equilibrium will be established as farmers adapt to the new situation and the more tolerant varieties become more widely cultivated. Whatever the scenario, it seems clear that CBSD will continue to be the primary constraint to cassava production in large areas of the GLCI Project target zone in the immediate future. Expanded control efforts are therefore strongly justified.

### **Other Pests/Diseases**

The annual surveys protocol of the GLCI Project made provision for the assessment of all of the major pests and diseases of cassava. Full assessments were made for cassava mealybug (CM), *Phenacoccus manihoti*, cassava green mite (CGM) (*Mononychellus tanajoa*) and cassava bacterial blight (CBB) (*Xanthomonas axonopodis* pv. *manihotis*), as well as the biocontrol agent of CM, the predatory mite *Typhlodromalus aripo*. In general, very low levels of damage were recorded for CM and CBB. Consequently, maps have not been provided for these. By contrast, significant levels of damage were recorded for CGM. The most severely affected areas were in north-western Tanzania.

Although *T. aripo* was infrequent throughout the surveyed area, it was completely absent in worst-affected districts of north-western Tanzania. These results suggest that a review of the overall effectiveness of the biocontrol activity of *T. aripo* is warranted across the East and Central Africa region. Supplementary agents may be required to ensure that adequate region-wide CGM control is achieved in the future. The survey protocol also provided the facility to record any other unusual pests/diseases encountered. Although survey teams did encounter other pests and diseases that were locally important, none of these occurred frequently enough or was causing sufficient damage to warrant further investigation.

### **Annual Disease Survey Maps and Priority Setting**

Maps 21-23 illustrate the results of the development of indexes of priority for CMD, CBSD and the two diseases combined. Combining different variables to produce a single index offers the advantage that one value can be generated that illustrates the overall 'weight' of the disease(s) and the relative success achieved to date in managing it(them). These values can be used both to gauge the success of on-going activities, as well as to target future interventions. The basic assumption on which these indexes are based is that 'bad disease + low availability of CMD-resistant varieties = high priority'. Clearly, there are other issues, in addition to disease and variety, that need to be taken into consideration when determining how best to prioritize activities. However, since cassava disease mitigation is the primary goal of GLCI, disease data must represent a key component of any prioritization exercise.

The most significant feature of the disease-specific priority maps for CMD and CBSD is the regionality. Thus, CMD high priority 'districts' are mostly in the areas most recently affected by the CMD pandemic: eastern DRC, south-eastern Burundi and north-western Tanzania. An important exception is the southernmost part of eastern DRC, where high incidences of the cultivation of CMD-resistant varieties have resulted in lower priority values than might have been expected. For CBSD, similarly, there is a strong regional pattern, with greatest priority identified for coastal 'districts' of Tanzania and the new outbreak hotspots in the Lake Zone of Tanzania and western Kenya. Combining the two datasets in an overall cassava virus disease priority map produces an interesting 'mosaic'-like outcome, with high priority 'districts' present in all of the main target areas of the Project zone. This provides justification for sustained activity in all project target areas for which data are available. Within-region or within-country differences should provide local Project teams with a basis for reviewing in-region or in-country activity prioritization. A notable example is Burundi, where increased focus on the Lake Tanganyika shoreline areas is strongly supported by the data. Considering the entire Project area, all of the highest priority 'districts' are in Tanzania, whilst the geographical area targeted there is close to half that of the entire project region. Two factors have impeded progress in GLCI's disease mitigation efforts in Tanzania. Firstly, the rapid spread of CBSD in the Lake Zone has greatly impeded improved variety multiplication and dissemination activities there. Secondly, concern about the new CBSD outbreak in the Great Lakes region has diverted attention away from the coastal region of Tanzania, which remains the zone worst affected by CBSD. Cassava stakeholders, including the research community, also seem to have underestimated the impact of cassava virus diseases in coastal areas. Attention has been diverted to the latest and newest epidemic in the Great Lakes, to the detriment of management efforts in the endemic zone. Perhaps the greatest single message arising from these survey data is that this situation needs to be rectified, and greater efforts are required from all stakeholders to address

cassava virus disease impacts in coastal regions. This recommendation is all the more important, in view of the interest of GLCI, and many other large-scale cassava projects, in the development of cassava as an income-generating option for rural communities. Opportunities for building cassava value chains are greatest for producers located close to the city ports of coastal East Africa, with the most important of these being Dar es Salaam, Mombasa, Tanga and Mtwara.

Prioritizing intervention areas is a valuable activity, but its value depends on the Project implementers having effective mitigation strategies available for use within targeted zones. Although there is good scientific understanding of CMD and the viruses that cause it, and CMD-resistant varieties are virtually immune to the causal viruses, this is not the case for CBSD. Much progress has been made in understanding the epidemiology of CBSD through the GLCI project, and the survey data presented here provide the first detailed regional status of the disease in East and Central Africa. Great progress has also been made in the last two years in understanding the nature of the viruses that cause CBSD and in developing diagnostics to detect and identify them. Currently, the greatest bottleneck to the management of CBSD is the lack of varieties with adequate levels of either resistance or tolerance. Tolerant varieties are widespread in coastal Tanzania, yet sustained high levels of CBSD incidence pose an on-going threat and mean that varieties that combine tolerance (infected plants do not incur major root loss) with resistance (plants are not readily infected) are urgently required. Whilst the current focus will necessarily focus on the identification and dissemination of the most tolerant varieties obtainable within the time-frame of the existing GLCI project, the central goal for the medium to long-term future should be the development of truly resistant varieties.



## 7. Acknowledgements

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## Annex 1 – Survey Teams

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# **GREAT LAKES CASSAVA INITIATIVE (GLCI)**



## **Annual Cassava Disease and Pest Surveillance under the GLCI Project**

*Compiled by J. Legg, IITA-Tanzania*

**June 2009**

## Introduction

In the Disease Objective of the Great Lakes Cassava Initiative (GLCI) project, annual cassava disease and pest surveillance surveys are an important element in the overall strategy for monitoring disease spread and forecasting changes. The survey approach used for the GLCI project will make use of experience gained from numerous previous initiatives conducted at regional level in East and Central Africa (Sseruwagi *et al.*, 2004; Legg *et al.*, 2006).

Data obtained from the surveys will be complementary to testing results obtained from the CBSV testing programme to be conducted at cassava planting material multiplication sites. In surveillance surveys of farmers' fields, 15 sites will be sampled per district for all districts, in order to provide a consistent approach and to allow for statistical comparisons between districts. For all districts, a minimum of one composite sample of ten leaflets (obtained from ten plants) will be obtained per site for CBSV testing. However, for those districts containing multiplication sites included in the CBSV testing programme, an additional one composite sample of ten leaflets (obtained from ten plants) will be obtained in order to give a total of 30 samples for the district. Since this is equivalent to the number of tested samples from multiplication sites, it will ensure that there are comparable statistical confidence limits for data from both farmer fields and cassava multiplication sites (95% confidence in detecting an incidence of 1%).

Annual surveillance surveys will be led in each country by the NARS involved in the GLCI project. Some of the NARS of target countries will be able to implement this work independently from the outset, but for those where support is required, this will be provided by IITA. Funds for the work are included within budgets for NARS organizations under the Disease Objective. The survey approach proposed has been designed to be achievable within a time period of less than 60 days in each country.

## Objectives

- To test for the presence of *Cassava brown streak virus* (CBSV) in farmers' fields, and provide CBSV incidence data that can be statistically compared with CBSV incidence data obtained from cassava multiplication sites assessed under the FERA/KEPHIS CBSV testing programme.
- To describe and map major arthropod pests and diseases in GLCI target countries and characterize the region-wide epidemiology of the principal virus diseases, cassava brown streak disease (CBSD) and cassava mosaic disease (CMD). Major pests are included in addition to CMD and CBSD, since localized outbreaks are common, and the GLCI project must be aware of these. These data will also feed into the project's comprehensive AGILIX/GOCOURSE pest and disease training programme.
- To provide data on all the major diseases and pests of cassava that will allow statistically meaningful comparisons to be made between different sampled 'districts' (or equivalent) in the same year and between 'districts' from one year to the next.
- To link with the DEWN activity in providing an effective regional pest and disease monitoring system

## Methods

### *i) Sampling 'domain'*

Surveys will be conducted in project target 'districts' (or equivalent) of target countries. The number of sampled 'districts' and their area will vary from country to country. Target 'district' numbers and sites proposed for sampling per 'district' are outlined in Table 1. For all countries and all districts, 15 'young' fields (3-6 months after planting) and 10 'old' fields (> 10 months after planting) will be sampled. 'Old' fields will be selected as close as possible to every second and every third 'young' field. Therefore, for each group of three 'young' fields, for the first, only a 'young' field will be sampled, whilst for the second and the third, a 'young' and then a neighbouring 'old' field will be sampled.

### *ii) Sampling timing*

There is no single ideal period for sampling in the six GLCI countries. Different pests and diseases are more effectively assessed at different times of the year. The best compromise is the third quarter of the year (June to September), when young crops are available, CBSV symptoms in both leaves and roots are readily seen and attack from some of the most important pests is also clearly evident. Sampling timing will be consistent for each country throughout the project to ensure that valid year-on-year comparisons can be made.

**Table 1. Sampling targets for disease surveillance (to be repeated annually)**

	<b>Burundi</b>	<b>DR Congo</b>	<b>Kenya</b>	<b>Rwanda</b>	<b>Tanzania</b>	<b>Uganda</b>
Number of 'districts'	16	14	15	16	37	15
Number of districts with CBSV-tested multiplication fields	8	7	8	7	16	8
Total number of 'young' fields sampled in districts with CBSV-tested multiplication fields	120	105	120	105	240	120
Total number of 'young' fields sampled in districts without CBSV-tested multiplication fields	120	105	105	135	315	105
Overall total number of 'young' fields	240	210	225	240	555	225

### *iii) Field selection*

Farmers' fields: Fields will be sampled along motorable roads running through target districts. Fields will be selected at regular intervals, determined by dividing the length of the route to be covered through the district by the number of sites to be sampled per district. Sampling sites will be selected according to the intervals determined for the district and where 3-6 months old cassava crops are

seen. These crops comprise the 'young' sampled field and will be sampled for the full range of cassava major pests and diseases. Mature crops (more than 10 months after planting) neighbouring these fields, and referred to as the 'old' sampled field, will be identified and sampled only for CBSD because in such fields it is possible to check for the necrosis symptoms that affect the tuberous roots. For every three 'young' fields, two 'old' fields will be sampled.

iv) *Field background information*

For each sampled field, details of location are recorded on the sampling data sheet. Separate sheets are provided for the 'young' and the 'old' fields. These include administrative level identifiers for the site, longitude/latitude and altitude recorded using a GPS and basic information about the cassava variety being sampled and the field environment (see Appendices 1 and 2). 'Neighbouring cassava fields' is the number of cassava fields that can be seen readily from the cassava field being sampled. Other crop plants being grown together with the sampled cassava are indicated under 'intercrop'. The approximate size of the sampled field is estimated.

v) *Sampling approach*

In both 'young' and 'old' fields, only the predominant variety is sampled, although other varieties are recorded (Sseruwagi *et al.*, 2004). This follows customary practice for recent surveys in the region, and ensures that data obtained for each variety can be compared statistically with data obtained for the same variety in other locations or for other varieties. The predominant variety is the variety that occurs most frequently in the selected field. In the 'young' field, 30 plants are sampled at regular intervals along an 'X' transect. In the 'old' field, 10 plants are sampled at regular intervals along an 'X' transect.

vi) *Data recorded in the 'young' field*

Severity and damage scores are as set out in the standardized IITA pest/disease scoring table provided as Appendix 3. Specific details for each of the major pests and diseases to be assessed under GLCI surveillance surveys are provided below:

**Cassava mosaic disease (CMD)**

The parameters taken for CMD will be symptom severity and infection type. Severity is scored on a scale of 1-5 where 1 represents no symptoms and 5 the most severe symptoms. Infection types are categorized as "C" (cutting-borne infection), "W" (whitefly-borne infection) or "H" healthy for uninfected plants. Where the lower first-formed leaves show symptoms, infection is assumed to be cutting-borne, whilst where only upper leaves show symptoms, infection is considered to be whitefly-borne. When assessing severity, only the infected portion of the plant is considered.

### **Whitefly abundance**

Adult whitefly (*Bemisia tabaci*) are counted on the top five apical leaves and nymphs are counted on the 14<sup>th</sup> leaf of the tallest shoot for 5 of the 30 plants sampled per field and the totals of individual counts are recorded separately.

### **Cassava bacterial blight (CBB)**

Cassava bacterial blight (CBB) severity is assessed by scoring severity of the disease on the 30 sampled plants using a scale of 1-5, where 1 represents no symptoms and 5 the most severe symptoms.

### **Cassava brown streak disease (CBSD)**

Leaf and shoot symptoms of CBSD are assessed for each of the thirty sampled plants using a severity scale of 1-5, where 1 represents no symptoms and 5 the most severe symptoms that include stem streaking and shoot tip die-back. In addition, in the 'stem' column of the datasheet, the presence or absence of CBSD stem symptoms is noted for each plant with '+' (for present) and '-' (for absent).

### **Sooty mould and whitefly physical damage assessments**

Sooty mould and physical damage on leaves caused by the feeding effects of whitefly are assessed using a scale of 1-5 on every second plant along the sampling transect. In these assessments, the effect on the whole plant is considered.

### **Cassava green mite (CGM) and cassava mealybug (CM) damage assessment**

The severities of CGM and CM are assessed on a scale of 1-5, where '1' represents no symptoms and '5' the most severe symptoms.

### ***Typhlodromalus aripo* (*T.aripo*), predatory mite of CGM**

The occurrence is assessed by carefully opening the shoot tip of the tallest shoot of every third plant (10 in total) and indicating presence by '+' and absence by '-'

### **Other observations**

It is important that the GLCI project is aware of the potential for occurrence and spread of completely novel (and possibly exotic) pests or diseases. As such, where any unusual pest, disease or apparent disease symptom is noted, a written note will be made on the field's datasheet and a picture should be taken. A rough assessment of the importance of the 'other' pest/disease should be made, where \*\*\* indicates severe and present on most or all sampled plants, \*\* indicates moderate and present on more than half of the sampled plants and \* indicates mild and present on less than half of the sampled plants.

### **CMD/CBSD in other varieties**

If the CMD or CBSD status in varieties that are NOT the predominant and sampled variety is greatly different to the predominant, sampled variety, a note should be made in the appropriate line at the bottom of the datasheet. For example, if the predominant variety that was sampled is CMD-resistant improved material, and the unsampled local variety has a high incidence of severe CMD, this should be noted in one sentence on the line 'CMD in other varieties'. A similar approach should be used for CBSD.

vii) *Data recorded in the 'old' field*

**Cassava brown streak disease (CBSD)**

Ten plants are examined along an 'X' transect of the 'old' field. For each of these plants, leaf and shoot symptoms are assessed as for the 'young' field, and the presence/absence of stem symptoms is noted. However, with the permission of the farmer, and coupled with the payment of an appropriate level of compensation (equivalent to the local market value of the fresh roots), the ten plants are dug up for assessment of root symptoms. All roots are then assessed by making five cross-section cuts with a knife or cutlass for each root. Each of the five cut sections is then scored separately using the pictorial severity scale provided as a laminated card (Appendix 4). Consequently, five scores are obtained for each of the sampled plants' roots. Images of unusual symptom types should be recorded using both written descriptions and by taking photos. Remarks should be added for non-sampled varieties where their CMD or CBSD disease status (leaf/stem symptoms) contrasts strongly with that of the predominant sampled variety.

viii) *Sample collection*

**Cassava mosaic disease (CMD)**

One CMD-diseased plant expressing symptoms typical of CMD in the 'young' field should be selected for leaf sampling. One leaflet of the topmost expanded leaf showing clear CMD symptoms is picked and rubbed, using the base of a microfuge tube, onto a single sample spot on a sheet of FTA paper. A piece of 'parafilm' is placed between the microfuge base and the leaf during the rubbing. If very unusual CMD symptoms are seen, an 'extra' sample may be collected on a separate FTA paper (kept separate from the main survey sample series and used ONLY for small numbers of unusual samples), making sure to clearly indicate the field and plant number next to the spot where the sample was rubbed onto the FTA card.

**Cassava brown streak disease (CBSD)**

For samples to be collected for CBSV diagnostics, the frequency of sampling will vary depending on whether or not a multiplication site being tested for CBSV is present in the district or not. For districts where a CBSV testing multiplication site is present, two out of every three sampled plants in the 'young' field will be used for CBSV sample collection (making two sets of ten composite samples). For every three plants along the 'X' transect, the second and third plant will be used. For districts where multiplication sites are not being tested for CBSV, every third plant in the 'young' field will be used for CBSV sample collection (making one set of ten composite samples). For each of the plants sampled for CBSV diagnostics, the central leaflet is picked from the second fully-expanded leaf (counting from the shoot apex) and this leaflet is stuck onto a sheet of blank newsprint using masking tape. Newsprint sheets are labeled at the top with site details (country, district, field number) and the plant number is written next to each leaflet after it is stuck in. This number should correspond with the plant number of the 'young field' datasheet, and a tick should be entered into the relevant space under the CBSD 'sample' column to indicate that that plant was sampled for CBSV diagnostics. Ten leaflets obtained from ten plants will be placed on a single blank newsprint sheet. Where 20 leaflets are collected from a single field (for districts with CBSV testing of multiplication



sites), two sheets of blank newsprint will be used. Following the completion of sampling, sheets of newsprint with attached leaflets will be placed into a herbarium press for storage through the duration of the survey. In the whole process of sampling and storage, moisture must be avoided to ensure good quality samples. Samples will need to be stored in a freezer (ideally -80°C) on arrival at the laboratory prior to testing. For countries where CBSV testing is not possible, samples should be sent by courier together with all necessary phytosanitary certification to the designated central testing laboratory.

### **Whiteflies**

*Bemisia tabaci* whitefly adults are collected from one in five 'young' fields using an aspirator. Care must be taken to distinguish between *B. tabaci* and *B. afer* adults based on the characteristic morphological distinguishing features. At least 10 adults should be collected per field, although the target should be more than thirty, with a maximum of 100. Collected whitefly adults are killed by adding 80% ethanol to the aspirator vessel and these are then transferred to a 2ml polythene sample tube to which a pencil-written label is added. The tube is then labeled externally with a permanent marker and sealed with parafilm. On the pencil-written label placed inside the tube, the following should be indicated: country (short-form e.g. Tz for Tanzania, Ug Uganda etc), field number, the species identity (in this case '*B. tabaci*'), and the date. On the outside of the tube, country and field number should be written BOTH on the top of the tube's lid, as well as on the side of the tube, using the permanent marker, before the tube is sealed with parafilm.

#### *ix) Data recording, collation and analysis*

Data will initially be recorded in the field using forms such as that appended to this document as Appendices 1 and 2. In year 2 and subsequently, a switch will be made to field data recording using hand-held PC devices pre-loaded with excel spreadsheets designed to handle data entry and allow simple data processing. Ideally, these should also have integrated GPS capability. A target will be to provide summarized data 'in real time' through uploading field-collected data to the Project web site at the end of each sampling day. Mapping will be done using these real-time collated data to provide up-to-date visual representations of the distributions and incidence/severity levels of each of the major pests and diseases.

Averaged disease and pest data for the district or equivalent level will allow for statistical comparisons to be made between districts within the same year and between districts from year to year. These data will enable assessments to be made of rates of disease change and will facilitate the forecasting of future patterns of pest spread or disease epidemic development. The complete dataset will provide the basis for sub-regional determinations of the epidemiology of the two main virus diseases, CMD and CBSD.

## References

Legg, J. P., Owor, B., Sseruwagi, P. and Ndunguru, J. 2006. Cassava mosaic virus disease in East and Central Africa: Epidemiology and management of a regional pandemic. *Advances in Virus Research* 67, 355-418.

Sseruwagi, P., Sserubombwe, W.S., Legg, J.P., Ndunguru, J. and Thresh, J.M. 2004. Methods of surveying the incidence and severity of cassava mosaic disease and whitefly vector populations on cassava in Africa: a review. *Virus Research* 100, 129-142.

# Appendix 1 GLCI DISEASE SURVEY DATA SHEET - Young Field

Country							Field Size (m <sup>2</sup> )						
Dist./Prov./Territoire							Age (months)						
Village/Sous-Colline							Cassava Vars.						
Latitude							Sampled Var.						
Longitude							Intercrop(s)						
Altitude (m)							Neighbouring Cassava Fields						
Date/Time													
Researcher(s)													
Plt.	Adult Whitefly	Whitefly Nymphs	Whitefly Damage	Sooty Mould	CGM sev.	T. aripo	CM sev.	CMD		CBSD			CBB sev.
								inf.	sev.	sev.	stem	sample	
1													
2													
3													
4													
5													
6													
7													
8													
9													
10													
11													
12													
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26													
27													
28													
29													
30													

Other Observations: \_\_\_\_\_  
 \_\_\_\_\_  
 \_\_\_\_\_

CMD in other varieties: \_\_\_\_\_  
 CBSD in other varieties: \_\_\_\_\_

## Appendix 2 GLCI DISEASE SURVEY DATA SHEET - Old Field

<b>Country</b>		<b>Field Size (m<sup>2</sup>)</b>	
<b>Dist./Prov./Territoire</b>		<b>Age (months)</b>	
<b>Village/Sous-Colline</b>		<b>Cassava Vars.</b>	
<b>Latitude</b>		<b>Sampled Var.</b>	
<b>Longitude</b>		<b>Intercrop(s)</b>	
<b>Altitude (m)</b>		<b>Neighbouring Cassava Fields</b>	
<b>Date/Time</b>			
<b>Researcher(s)</b>			

	Plant 1					Plant 2					Plant 3					Plant 4					Plant 5				
Leaf																									
Stem																									
Root #																									
Rootsev	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
Root 1																									
Root 2																									
Root 3																									
Root 4																									
Root 5																									
Root 6																									
Root 7																									
Root 8																									
Root 9																									
Root 10																									

	Plant 6					Plant 7					Plant 8					Plant 9					Plant 10				
Leaf																									
Stem																									
Root #																									
Rootsev	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
Root 1																									
Root 2																									
Root 3																									
Root 4																									
Root 5																									
Root 6																									
Root 7																									
Root 8																									
Root 9																									
Root 10																									

Other Observations: \_\_\_\_\_  
 \_\_\_\_\_  
 \_\_\_\_\_

CMD in other varieties: \_\_\_\_\_

CBSD in other varieties: \_\_\_\_\_

### Appendix 3. Pest and Disease abundance classes and damage scores

Pest	Abundance classes and damage scores				
	1	2	3	4	5
<b>1. CMD</b>	<ul style="list-style-type: none"> <li>no symptoms</li> </ul>	<ul style="list-style-type: none"> <li>mild chlorotic mosaic on leaves</li> <li>little distortion of leaf shape</li> </ul>	<ul style="list-style-type: none"> <li>moderate chlorotic mosaic on leaves</li> <li>moderate distortion of leaf shape with cupping</li> </ul>	<ul style="list-style-type: none"> <li>bright yellow chlorosis covering much of leaf area</li> <li>severe distortion of leaf shape with reduced size</li> <li>down-turned petioles</li> </ul>	<ul style="list-style-type: none"> <li>bright yellow chlorosis affecting much of leaf area</li> <li>severe distortion of leaf shape with reduced size</li> <li>down-turned petioles with leaf drop</li> <li>plant stunted</li> </ul>
<b>2. CBSD</b>	<ul style="list-style-type: none"> <li>no symptoms on leaves or stems</li> </ul>	<ul style="list-style-type: none"> <li>mild/slight vein yellowing or chlorotic blotches on leaves</li> <li>no brown streaks/lesions on green stem portions</li> </ul>	<ul style="list-style-type: none"> <li>mild/slight vein yellowing or chlorotic blotches on leaves</li> <li>mild brown streaks/lesions on green stem portions</li> </ul>	<ul style="list-style-type: none"> <li>severe/extensive vein yellowing or chlorotic blotches on leaves</li> <li>severe brown streaks/lesions on green stem portions</li> <li>no defoliation, stem dieback or stunting</li> </ul>	<ul style="list-style-type: none"> <li>severe/extensive vein yellowing or chlorotic blotches on leaves</li> <li>severe brown streaks/lesions on green stem portions</li> <li>defoliation, stem dieback and stunting</li> </ul>
<b>3. CBB</b>	<ul style="list-style-type: none"> <li>no symptoms</li> </ul>	<ul style="list-style-type: none"> <li>angular leaf spotting only</li> </ul>	<ul style="list-style-type: none"> <li>wilting</li> <li>angular leaf spots enlarged</li> <li>leaf blight</li> <li>defoliation</li> <li>gum exudates on stem/petioles</li> </ul>	<ul style="list-style-type: none"> <li>wilting</li> <li>blighting</li> <li>defoliation</li> <li>gum exudation</li> <li>shoot tip die-back</li> </ul>	<ul style="list-style-type: none"> <li>wilting and blighting</li> <li>defoliation and gum exudation</li> <li>abortive lateral shoot formation</li> <li>stunting</li> <li>complete die-back</li> </ul>
<b>4. Cassava green mite</b>	<ul style="list-style-type: none"> <li>no damage</li> </ul>	<ul style="list-style-type: none"> <li>&lt;5% chlorotic</li> </ul>	<ul style="list-style-type: none"> <li>&gt;5%, &lt;50% chlorotic</li> </ul>	<ul style="list-style-type: none"> <li>&gt;50% chlorotic</li> </ul>	<ul style="list-style-type: none"> <li>dead leaf, leaf drop</li> </ul>
<b>5. Cassava mealybug</b>	<ul style="list-style-type: none"> <li>no damage</li> </ul>	<ul style="list-style-type: none"> <li>margins curling</li> </ul>	<ul style="list-style-type: none"> <li>slight bunchy top</li> </ul>	<ul style="list-style-type: none"> <li>strong bunchy top</li> </ul>	<ul style="list-style-type: none"> <li>complete defoliation</li> </ul>
<b>6. Whitefly abundance</b>	<ul style="list-style-type: none"> <li>actual count</li> </ul>	<ul style="list-style-type: none"> <li>N/A</li> </ul>	<ul style="list-style-type: none"> <li>N/A</li> </ul>	<ul style="list-style-type: none"> <li>N/A</li> </ul>	<ul style="list-style-type: none"> <li>N/A</li> </ul>
<b>7. Whitefly direct damage</b>	<ul style="list-style-type: none"> <li>none</li> </ul>	<ul style="list-style-type: none"> <li>mild chlorotic blotches on &lt; 10% of leaves</li> </ul>	<ul style="list-style-type: none"> <li>moderate chlorotic blotches on 10-30% of leaves</li> </ul>	<ul style="list-style-type: none"> <li>general yellowing of upper leaves</li> <li>yellowing or chlorosis on 30-50% of leaves</li> </ul>	<ul style="list-style-type: none"> <li>yellowing and deformation of upper leaves</li> <li>chlorosis on &gt; 50% of leaves</li> <li>plant stunting</li> </ul>
<b>8. Whitefly-induced sooty mould</b>	<ul style="list-style-type: none"> <li>none</li> </ul>	<ul style="list-style-type: none"> <li>mild sooty mould on &lt; 5% of leaves</li> </ul>	<ul style="list-style-type: none"> <li>mild sooty mould on 5-20% of leaves</li> </ul>	<ul style="list-style-type: none"> <li>moderate sooty mould on &gt; 20% of leaves</li> <li>mild leaf curling</li> </ul>	<ul style="list-style-type: none"> <li>heavy sooty mould on 20-50% of leaves</li> <li>strong leaf curling of lower leaves</li> <li>stunted growth of bottom half of plant</li> </ul>

## Appendix 4. CBSD root severity scoring sheet

