Institution: University of Greenwich

Unit of Assessment: 6 - Agriculture, Veterinary and Food Science

Title of case study: Mitigating the devastating impact of cassava virus diseases on African smallholder farmers and the cassava value chain by transforming policy and practice

Period when the underpinning research was undertaken: January 2012 – December 2019

Details of staff conducting the underpinning research from the submitting unit:

Name(s):	Role(s) (e.g. job title):	Period(s) employed by submitting HEI:
Maruthi M N Gowda	Prof. of Molecular Plant Pathology	10/09/2001 - to present
Rory Hillocks	Senior scientist (retired)	01/05/1996 – 15/12/2015
Sophie Bouvaine	Research Fellow	07/05/2013 – to present
Keith Tomlins	Professor of Food Science (retired)	01/05/1996 – 31/08/2020

Period when the claimed impact occurred: August 2013 - July 2020

Is this case study continued from a case study submitted in 2014? N

1. Summary of the impact

Cassava provides more than half of daily dietary requirements for over 450 million farmers and their households in Sub-Saharan Africa (SSA) but is affected by two major viral disease epidemics. Strategic research at the University of Greenwich aimed to control the epidemics and sustain the food production and livelihoods of millions of people. For farmers, our research on curing cassava varieties from viral infections and identification of resistant varieties has contributed to reduced disease incidences and increased cassava production in the five worst affected countries in SSA (Kenya, Malawi, Mozambique, Tanzania, and Uganda). This also led to new enterprise activities for farmers through producing and selling high quality seed and at the policy level, our research has informed the Tanzania Seed Act amendment by developing the first cassava seed system in Tanzania, and this was replicated in Rwanda and Burundi.

2. Underpinning research

Cassava (*Manihot esculenta*) is a tuberous climate-resilient starchy root and a vital source of food and income for over 450 million people in SSA. This is more so the case during extreme weather conditions when all other crops fail and thus it is an important source of household food security as well as a significant avenue for family income, particularly women farmers. However, two viral diseases, cassava mosaic disease (CMD - caused by cassava mosaic begomoviruses or CMBs), and cassava brown streak disease (CBSD - caused by cassava brown streak ipomoviruses or CBSIs), have severely affected cassava production. A pandemic of CMD that began in the 1990s and a new epidemic of CBSD from mid 2000s has affected cassava farmers in 11 SSA countries. CMD is estimated to cause annual losses between US$ 1.2-2.4 billion while CBSD causes losses up to US$750 million. This is because farmers cannot protect their crop against these diseases as they cannot afford expensive pesticides. Using healthy planting material of the disease-resistant cassava varieties is therefore the only sustainable way for controlling the two cassava diseases in Africa.

The University of Greenwich's Natural Resources Institute (NRI) has been at the forefront of managing both CMD and CBSD for over three decades. The most recent research has been led by **Professor Maruthi M N Gowda** (referred to in journal references as **Maruthi, MN**), and together with a team of researchers (**Hillocks**, **Bouvaine**, **Tomlins** and three PhD students) he has developed highly reliable diagnostic polymerase chain reaction (PCR) techniques for the accurate diagnosis of CMBs and CBSIs [**3.1**]. PCR is a highly accurate forensic technique that can detect the presence of virus infection in any infected samples (e.g., used for detecting Coronavirus in humans). PCR was highly useful for us to separate the virus-infected cassava plants from healthy ones. Our new protocols were high throughput, reliable and more efficient

(between 50 to 300%) compared to existing methods for detecting the cassava viruses [**3.2**]. **Tomlins** led the EU funded *CassavaGmarkets* project, which part funded this work. **Bouvaine** and **Hillocks** were involved in the supervision of three PhD students (Abarshi, Mohammed, Otti) that contributed to diagnostic work and **Hillocks** also provided field expertise on cassava diseases.

In addition, **Gowda** used chemo- and thermo-therapy treatments and tissue culturing procedures for eliminating virus infections from cassava plants [**3.3**]. The use of chemo- and thermo-therapy kills virus particles in infected plant tissues (similar to killing cancer cells in humans), which are then regenerated by tissue culturing of treated tissues. **Gowda** then used PCR for confirming the absence of viruses in the treated tissues and plants. All this was achieved in the Bill and Melinda Gates Foundation (BMGF) funded project '*5CP*' (2012-2016), led by the International Institute of Agriculture (IITA) Tanzania. In this project, NRI was the only non-African partner and made crucial contributions by curing over 2500 plants belonging to 31 varieties from the two viral infections. This was highly significant as prior to our research, no regional effort was made to cure cassava to exchange cassava varieties between the five most affected countries (Kenya, Malawi, Mozambique, Tanzania and Uganda).

The research involved importing diseased cassava plants to NRI from the five countries and curing them from viral infections in the UK in 2012-2013 using our innovative chemo- and thermo-therapy protocols together with tissue culture and virus indexing by PCR tests. The virus-free, certified, clean, tissue-cultured cassava plants (2500) were generated and sent back to all five countries by July 2013 via the commercial partner Genotypic International Limited in Kenya (a commercial service provider for further multiplying tissue cultured cassava) [**3.3, 3.4**]. This facilitated the first ever regional exchange of improved cassava varieties by August 2014 between the aforementioned five eastern and southern African countries, and importantly provided the healthy planting material to many farmers for cultivation. "NRI had a pivotal role to play in this effort… to clean cassava from virus infections… and …this task was done outstandingly well" [**5.1**]. Apart from being a key pillar of the cassava disease removal strategy, the development of clean cassava was geared to bringing about many additional benefits for farmer household prosperity and local economies, as described in the impact section of this case study. Among the 31 varieties investigated, NRI has more recently also identified new sources of virus resistance using state of the art next generation sequencing technologies such as RNA-Seq [**3.5**] as well as using them in cassava breeding in Tanzania [**3.6**]. The implications of this for future impacts are that farmer-preferred cassava varieties resistant to both diseases will be developed quicker and thus minimize disease infections and increase food security of over 450 million people in Africa.

3. References to the research

1. Abarshi MM**,** Mohammed IU, Jeremiah SC, Legg JP, Lava Kumar P, **Hillocks RJ**, **Maruthi MN**, 2012. Multiplex RT-PCR assays for the simultaneous detection of both RNA and DNA viruses infecting cassava and the common occurrence of mixed infections by two cassava brown streak viruses in East Africa. Journal of Virological Methods 179: 176– 184. https://doi.org/10.1016/j.jviromet.2011.10.020
2. Otti G, **Bouvaine S**, Kimata B, Mkamillo G, Kumar PL, **Tomlins K**, **Maruthi MN,** 2016. High throughput multiplex real time PCR assay for the simultaneous quantification of DNA and RNA viruses infecting cassava plants. Journal of Applied Microbiology 120: 13461356. https://doi.org/10.1111/jam.13043 [***REF2 Submission: Identifier 14252]***
3. **Maruthi MN**, Whitfield C, Otti G, Tumwegamire S, Kanju E, Legg JP, Mkamilo G, Kawuki R, Benesi I, Mhone A, Zacarias A, Munga T, Mwatuni F, Mbugua E, 2019, A method for generating virus-free cassava plants to combat viral disease epidemics in Africa. Physiological and Molecular Plant Pathology 105:77-87 https://doi.org/10.1016/j.pmpp.2018.09.002
4. Tumwegamire S, Kanju E, Legg JP, Shirima R, Kombo S, Mkamilo G, Mtunda K, Sichalwe K, Kulembeka H, Ndyetabula I, Saleh H, Kawuki R, Alicai T, Adiga G, Benesi I, Mhone A, Zacarias A, Nicosa N, Matsimbe SF, Munga T, Ateka E, Navangi L, **Maruthi MN**, Mwatuni F, Ngudo G, Mwangangi M, Mbugua E, Ndunguru J, Rajabu C, Mark D, 2018, The process and

lessons of exchanging and managing in-vitro elite germplasm to combat CBSD and CMD in Eastern and Southern Africa. Food Security 10: 351-368 https://doi.org/10.1007/s12571-018-0779-2
5. **Maruthi MN**, **Bouvaine S**, Tufan HA, Mohammed IU, **Hillocks RJ**, 2014. Transcriptional response of virus-infected cassava and identification of putative sources of resistance for cassava brown streak disease. PLoS ONE 9(5): e96642. https://doi.org/10.1371/journal.pone.0096642
6. Masinde EA, Mkamillo G, Ogendo JO, **Hillocks R**, Mulwa RMS, Kimata B, **Maruthi MN,** 2017. Genotype by environment interactions in identifying cassava (*Manihot esculenta* Crantz) resistant to cassava brown streak disease. Fields Crops Research 215: 39-48. http://dx.doi.org/10.1016/j.fcr.2017.10.001

Major research grants and NRI leads:

1. **Gowda**. *Great Lakes Cassava Initiative (GLCI) project*, 2008-2012, funded by the Bill and Melinda Gates Foundation (BMGF), led by the Catholic Relief Services-USA in which NRI was a key partner, US$21.8 million. http://pgpublications.squarespace.com/the-greatlakes-cassava-initia/
2. **Gowda**. *New Cassava Varieties and Clean Seed to Combat CBSD and CMD (5CP)*, 20122017, funded by the BMGF, led by IITA-Tanzania, US$6.2 million. NRI was the sole nonAfrican partner in *5CP* and led research on cleaning cassava from virus infections. https://www.iita.org/news-item/project-brings-ray-hope-fight-cassava-viruses-africa/
3. **Gowda**. *Limiting the impact of cassava brown streak disease on smallholders, women and the cassava value chain (LimitCBSD)*, 2012-2016, African Union Commission (AUC), led by NRI, Euro0.78 million. https://www.nri.org/latest/news/2013/new-project-to-continuebattle-against-cassava-disease

ninoand-cassava-diseases

4. Details of the impact

The harm caused by cassava virus diseases in Sub-Saharan Africa (SSA) was considerable by the time the CBSD started spreading fast in the mid-2000s, as more than half of all cassava plants were already infected with CMD on an area of 3 million square kilometres. The two diseases together caused estimated annual losses of about USD3,000,000,000 (Thresh et al., 1997, *African Journal of Root and Tuber Crops* 2, 13-19; **Hillocks** and **Maruthi**, 2015, *Food Chain* 5, 116122) to some of the poorest people on the planet who depend on cassava for food and income, particularly during droughts. Through *5CP*, we supplied virus clean and improved cassava varieties resistant/ tolerant to both diseases, which was the only sustainable way to control the epidemics. The impact of our research was felt at several levels.

NRI research benefitted farmers and cassava seed entrepreneurs in Tanzania. At the farmer level, the partners of *5CP*, supported by NRI's research, produced clean (virus-free) cassava varieties, and been given free to farmers and cassava seed entrepreneurs (CSEs) since 2014 in Tanzania. The *5CP* went on to produce a total of 3,665,406 'breeders seed' (first step in the development of a variety) of 10 cassava varieties by 2017 [**5.1, 5.7-5.10** and the *5CP* project final report].

This work of *5CP,* ably supported by NRI through virus diagnosis, tissue culture and training, created awareness and high demand for healthy cassava seed by farmers desperate for good quality seed resistant to the two diseases devastating their livelihoods [**5.1-5.3, 5.7-5.10**]. This transformative impact on farmers, their households and communities were recognised by major donors such as the Bill and Melinda Gates Foundation (BMGF) and it led them to further fund two projects for commercialisation of clean cassava seed and development of a formal cassava seed system in Tanzania for the first time [**5.7**]. The BEST Cassava Seed Champion projects have already trained a total of 280 CSEs, which sold cassava seed to approximately 47,000 smallholder farmers by the end of 2019 growing season, and indirectly benefitted over 1,000,000 farmers and their households in 11 Regions in Tanzania alone [**5.1, 5.7**]. "All these benefits would not have

been possible without the participation and capability of NRI to clean, virus index and introduction of cassava in 5CP. The economic and food security benefits of this work has been the greatest I have seen in my 40 years of work on cassava" [**5.2**].

The work also led to a change in the spending habits of Tanzanian farmers. The commercialisation of clean seed, and success of an entirely new market for it, demonstrated a historical behavioural change among Tanzanian farmers; the willingness to purchase healthy cassava seed from CSEs, where previously they relied solely on using their own seed for planting in the new season. This attests in the most meaningful way to the benefits to productivity and thus livelihoods they experienced first-hand from use of the improved cassava varieties [**5.1, 5.2, 5.5**]. "Yes, there is increasing behavioural change in cassava farmers and are willing to pay and buy cassava planting materials" [**5.5**].

Research conducted at NRI informed the amendment in the Tanzania Seed Act. At the policy level, our procedures for cleaning cassava from virus infections had the most significant impact as they became a key part of developing cassava seed systems and institutionalising safe cleaning procedures in Tanzania in 2017 [**5.6**]. They are also implemented in Rwanda and Burundi [**5.5**]. They were used in another objective of the *5CP* project to inform an amendment to the Tanzania Seed Act (2017) that regulates cassava seed health. It made, for the first time, lab testing for viruses and tissue culturing compulsory for developing pre-basic and basic cassava seed (seed prior commercialisation) [**5.6**] (see Table 15, Page 5 of the Amended Tanzania Seed Act). This was the first example where detailed guidelines for cassava seed certification were formally appended to legislation anywhere in east and southern Africa. Similar updates to seed acts are being implemented in Rwanda and Burundi, supported by the IITA. "The progress achieved with NRI in improving seed health has now been transferred to Burundi, Rwanda and Eastern DRC, and is being recommended now Africa-wide" [**5.1, 5.5]**.

The exchange of cassava germplasm between the five affected countries via *5CP* in 2014 was also the first of its kind, providing access to the best cassava varieties available in the region to both farmers and researchers, although the impact has been greatest in Tanzania due to additional funding from donors (e.g., BEST Cassava). The varieties Mkumba and Tz130 developed in Tanzania, for example, are now found to be resistant to both diseases in Uganda and Malawi and are released as new varieties in both countries in 2019. Similarly, the varieties Orera and Eyope developed in Mozambique were found suitable for growing in Tanzania and these are now released for farmer cultivation since 2017. In other projects e.g., *LimitCBSD* (2012-2015) funded by the African Union Commission and led by **Gowda**, these improved varieties have been crossed with farmer-preferred local varieties. This has led to the development of new cassava varieties with increased resistance to both diseases. "These virus-resistant cassava varieties directly impact in the lives of nearly 70 million farmers in East, Central and Southern Africa regions" [**5.3**]. The upscale of all these activities was seen in the general increase in cassava production and revival of cassava production and industries [**5.1, 5.5**].

Impact by NRI research is further recognised by additional funded projects that create wider and continuing impact in African countries. **Gowda's** research has created further wider impact as the successes achieved so far have led to additional investment from donors [**5.3-5.5, 5.7**]. Our clean cassava varieties are being used in the following projects on different aspects of cassava research and development:

a. *NextGen cassava project* phase I and II (2014-2022), funded by the BMGF, led by the Cornell University is using some of the NRI cleaned *5CP* cassava varieties in their breeding program for rapid integration of desirable agronomic traits. This project has created continent-wide impact as it operates in the western, eastern and southern Africa [**5.3**].
b. *African cassava whitefly project* (ACWP) phases I and II (2014-2022), also funded by the BMGF, led by NRI is using *5CP* cassava in their pre-breeding program for developing cassava resistant to whiteflies, which spreads both CMD and CBSD.
c. *Action control CBSD* - The International Fund for Agricultural Development and the United States Agency for International Development each funded a replica of the *5CP* project in Rwanda and Burundi, and DR Congo in 2018, respectively. Their aim is multiplying and

distributing the best 15 cassava varieties to farmers. These efforts have been replicating the success experienced in Tanzania in *5CP* in the three new countries [**5.5**].

d. *LimitCBSD* (2012-2016) and *DualCassava* (2018-2021), both led by **Gowda** and funded by the African Union Commission have used the *5CP* varieties in advanced research on gene mining for virus resistance using next generation sequencing technologies.

An impact of all these efforts is an overall 25% increase in cassava production in the eastern African countries from 23,900,000 tonnes in 2010 at the peak of the epidemics to 30,100,000 tonnes in 2018 (FAOStat, 2019) [**5.3, 5.4**]. "The famers who have accessed the improved varieties have indeed gained increased productivity which has resulted in food security and better incomes from the surplus roots" [**5.5**].

5. Sources to corroborate the impact

1. Testimonial 1 on NRI's contributions in the 5CP Project and their impact provided by a *5CP* project leader Dr James Legg from the Tanzania branch of the International Institute of Tropical Agriculture (IITA).
2. Testimonial 2 provided by Dr Geoffrey Mkamilo, the Director General of Tanzania Agricultural Research Institute, Dodoma.
3. Testimonial 3 provided by Dr Chiedozie Egesi, leader of the NextGen Cassava project, Cornell University.
4. NRI's work impacting wider African countries is evidenced in Testimonial 4 given by Prof. Ibrahim Ahmad, Kebbi State University of Science and Technology, Nigeria of the wider implication of NRI's research in West Africa.
5. Testimonial 5 provided by the 5CP project manager Dr Silver Tumwegamire from the Rwanda branch of IITA.
6. The amended Seed Act of Tanzania by the Government of Tanzania recommends lab testing and tissue culture plantlets (ideas came from NRI-developed protocols) for the first time for preventing CBSD spread as part of cassava seed act (see Page 5, Table 15).
7. The MEDA's Best cassava projects records their impact on cassava seed system. MEDA's BEST cassava projects; Tanzania | building an economically sustainable seed system for cassava in Tanzania (best cassava)
8. The IITA records the great progress made in the 5CP project https://www.iita.org/news-item/iita-led-5cp-project-reports-great-strides-regional-exchange-improved-cassava-varieties/
9. The IITA records the closing of the 5CP project and it's achievements https://www.iita.org/news-item/project-brings-ray-hope-fight-cassava-viruses-africa/
10. 5CP received wider publicity in local and international Newspapers;
    a. Tanzania: Cassava Disease Control Underway, August 1, 2016 | AllAfrica.com (South Africa)
    b. Project releases disease-resistant cassava plantlets, April 15, 2014 | SciDev.net (United Kingdom)