The International Treaty
ON PLANT GENETIC RESOURCES FOR FOOD AND AGRICULTURE

Full Project Proposal

Third Call for Proposals under the Benefit-sharing Fund

Deadline for submitting full project proposal: 5th of December 2014
at Treaty-Fund@fao.org and PGRFA-Treaty@fao.org

TABLE OF CONTENTS

PROJECT PROPOSAL COVER SHEET

Project No. _____ (*For Treaty use. Do not write anything here)*

Project Title: Project Title: Genetic and trait charaterisation of farmer and genebank sources of bambara groundnut for the development of drought tolerant lines in sub-Saharan Africa and Southeast Asia

Project duration: 36 months

Target crops: Bambara groundnut (*Vigna subterranea* (L.) Verdc.)

Targeted developing country/ies Malaysia (L), Nigeria (P), Ghana (P), Indonesia (P)

Other Contracting Party/ies involved : Dr Michael Abberton (MA), the International Institute for Tropical Institute, Nigeria (IITA); Dr Joseph Nketiah Berchie (JB), Council for Scientific and Industrial Research-Crops Research Institute, Ghana (CSIR-CRI); Prof Dr lr Satriyas Ilyas (SI), Bogor Agricultural University, Indonesia (BAU).

Project geographic extension (km²) 136,281 (Ghana) + 1,428 (Nigeria) + 405 (Indonesia) + 0.05 (Malaysia) = 138,114 [or global if taking into account the scope of the online platform, BamNetwork]

Total requested funding (USD) 499,999

Total co-funding (USD) 813,104

Please select the type of project you are applying for:

☒ Multi-country Co-development and Transfer of Technology project (Window 3)

Applicant

Name of Organization: Crops For the Future Research Centre (CFFRC)

Type of organization: Not for profit research company

Project Contact: (*name and position)* Dr Sean Mayes (SM), Research Programme Director and Theme Leader for Biotechnology and Crop Genetics

E-mail address: sean.mayes@nottingham.ac.uk

Telephone: +6(03) 8924 8799; Fax: +6(03) 8924 87

SECTION A: EXECUTIVE SUMMARY

1. Executive summary

*Climate change is predicted to increase the frequency and severity of drought-associated yield losses in many parts of the world. It will have the greatest impact among resource poor farmers in developing countries. One approach to mitigate these effects and to help secure food security in the face of climate change is to encourage the wider use of existing drought tolerant, but underutilised, species such as bambara groundnut (*Vigna subterranea *(L) Verc). This can be achieved through the evaluation of existing plant genetic and trait diversity, and the development of new material with grower and user-selected traits. The current project details a Sub-Saharan African – Southeast Asian research collaboration to improve beneficial traits such as drought tolerance, while reducing the disadvantages of negative traits, such as long cooking times.*

This project has, at its core, a marker supported international breeding and selection programme for bambara groundnut (*Vigna subterranea* (L.) Verdc.) with a focus on Sub-Saharan Africa and Southeast Asia. The aim is to improve an already nutritious and drought resilient legume to promote food security, environmental protection and income generation for the world's most vulnerable regions.

Underlying a number of the biological challenges that bambara groundnut faces - a representative of underutilised crop species in general - there is a lack of:

A. quantitative and comparative data on traits of farmer-defined importance;
B. purified genetic lines, mixes and controlled crosses;
C. knowledge of optimal field management and genotype-by-environment interactions;
D. replicated and properly designed multi-locational field trials leading to locally selected varieties.

Research on the crop has been on-going for more than 20 years but there has not been a concerted effort to address the multi-faceted problems at a scale needed to drive it out of the status of being a neglected crop.

Further development of bambara groundnut through a structured trait evaluation and breeding programme will create 'climate change ready' pre-breeding lines, varieties and variety mixes that can produce yield in regions unsuitable for major crops and particularly in harsh marginal soils.

<u>Objectives</u>

One main objective of this project is to conserve, develop and evaluate the crop's genetic diversity with material sourced from current farmer landraces, *ex-situ* genebank material and recently developed novel pure lines and crosses. A common set and location-determined sub-sets of germplasm will be identified and tested for location-specific suitability. Previous socioeconomic assessments and end-user preference surveys have helped to identify initial traits for improvement and interaction with Partners and their extension services will lead to a more detailed understanding and refinement of required plant ideotypes during the project.

This will be supported by another main objective, trait analysis (including physiological responses and genetic mapping of trait loci) to give a more accurate and richer understanding of the legume's biology and the mechanisms involved that allow production in marginal and hostile environments.

<u>Targeted outputs</u>

The targeted outputs will be released lines and line mixes with improved drought tolerance and reduced cooking time, which have been selected for particular agro-environments by local farmers and that are acceptable to local consumers.

A major focus will be on the conservation of all genetic material (*in-situ* and *ex-situ*) generated regardless of the breeding status of such material, together with the open access datasets generated using that material.

Two low income, low resource agro-ecological regions will be studied and targeted by the project: sub-tropical West Africa, the crop's place of origin, and humid tropical Southeast Asia, the most recent area of substantial cultivation. Drought is a significant driver of the current distribution of farmers of bambara groundnut in the former, while climate change predictions suggest periodic and intermittent drought will become increasingly common during the annual cycle in the latter (IPCC 2014).

Beneficiaries

Direct beneficiaries in the project's target areas will be researchers through capacity building, participatory farmers through access to novel and improved seed sources, and non-participatory farmers reached through Partner extension systems. Indirect beneficiaries will be numerous as this crop is grown widely in Sub-Saharan Africa and Southeast Asia, albeit at small-scale. Bambara groundnut is a resilient, reliable and cheap source of nutritious food which already has wide appeal to its producers, processors and consumers. In addition, the crop contributes to mixed and small-scale farming through its ability to fix nitrogen even in poor and hostile soils.

Outcome: To improve adaptation to climate change and enhance the food security of resource-poor farmers in selected developing countries, by strengthening the sustainable management of plant genetic resources for food and agriculture (PGRFA)

This crop serves as an exemplar for other underutilised crops: lessons learnt from this project have the potential to be applied to other neglected minor crops. The long-term impact of this project to eradicate extreme poverty and hunger and ensure environmental sustainability is secured through:

- the strengthening of an existing West African (CSIR-CRI) and a Southeast Asian (BAU) centre of bambara groundnut research,
- the development of a new centre in Malaysia (CFFRC),
- the conservation and distribution of genetic and data resources, which will underpin continued breeding and release of improved material to farmers in both regions, through a well-established CGIAR centre (IITA);
- while the linkages developed between Africa and Asia will also support multi-regional research capacity.

SECTION B: PROJECT DESCRIPTION AND CONTENTS

2.1. Problem definition

Drought stress is predicted to become more severe under most climate change scenarios. This may reduce major crop yields or even no longer make those crops a viable option in certain areas. Enhancing drought tolerance in underutilised crops and beginning to understand its mechanisms involved in such crops can increase food security for resource poor farmers. However, many underutilised crops also have detrimental traits, which can inhibit farmers from growing the crop and limit its consumer demand.

This project's approach is to capture, preserve and evaluate the existing genetic variation of bambara groundnut from farmer's fields, genebanks and novel material previously developed, especially in regard to priority agronomic and socioeconomic/processing traits, *viz*. drought tolerance and cookability. Drought tolerance is a resilience trait that allows the crop to produce a yield during extreme and unpredictable dry spells, which are projected to increase with climate change (IPCC 2014). This will be exacerbated by poor nutrient and free draining soils, such as are common in the target regions. Improving bambara groundnut cookability (i.e. reducing its cooking time) has obvious potential benefits to the consumer in terms of saving labour, fuel and the environmental impact of burning fuel (the beans are typically cooked on open wooden and clay stoves in West Africa). Initial socioeconomic surveys have consistently found that the long cooking time (five hours) is the end-user's top priority (Adzawla et al. 2014, Olayide 2014; Attachments A and B). Reduced cooking times may also allow the crop to be used and processed in novel ways due to the altered physical properties of the reduced cooking time lines. The potential effect on storage pests and the seed viability of such reduced cooking time lines will also need to be assessed. This finding is in agreement with formal and informal discussions, e.g. the joint CSIR-CRI and CFFRC workshop, '3rd international bambara groundnut workshop', in Accra, Ghana in September 2013, and the Bioversity-ISF workshops, 'National innovation platform workshop on developing value chains of Amaranth and Bambara groundnut, in Harare, Zimbabwe and Cotonou, Benin in June-July 2014, as well as CFFRC partner discussions in Benin, Nigeria, Ghana, Zimbabwe, Botswana and South Africa, July-August 2014. Reducing cooking time is likely to increase demand, the size of the market, the range of value-added products and so the incomes of bambara groundnut farmers.

2.2. Project objectives: Overall and specific objectives

The overall objective of this project is to improve adaptation to climate change and enhance the food security of resource-poor farmers in selected developing countries, by strengthening the sustainable management and use of plant genetic resources for food and agriculture (PGRFA).

There are four specific objectives of the project:

1. To conserve and make available bambara groundnut PGRFA for further utilisation by farmers and researchers, allowing farmer-led selection of germplasm.
2. To breed bambara groundnut lines for improved drought tolerance and cookability, which are adapted to local environments, leading to more stable yields of bambara groundnut with shorter cooking times.
3. To create, make available and actively disseminate information on scientific and technical matters related to bambara groundnut PGRFA, including genotypic and phenotypic data associated with specific lines, to provide materials for continued breeding development through researchers and farmers.
4. To build the capacity of resource-poor farmers and researchers to characterise, conserve and manage PGRFA in Sub-Saharan African and Southeast Asian regions, which are particularly

vulnerable to climate change, leading to the continual conservation and development of improved lines for farmers.

2.3. Targeted outputs, activities and related methodology of implementation

The project's objectives will be carried out by subsets of 11 activities, each with its own targets and assumptions for achieving targeted outputs and outcomes, as illustrated in the logical framework (Appendix 2):

1.1 Collect and collate farmer landraces, selected landraces from genebanks and available novel pure lines and crosses (500 accessions) (1-6 months; IITA and CFFRC to jointly lead; Nigeria).
1.2 Multiply (at least 1,500 seeds per accession/line) selected common core and a sub-set of germplasm expected to be adapted to specific research partner environments ('local') to form the basic material for selection for the rest of the project (1-12 months; ; IITA and CFFRC to jointly lead; Nigeria and Malaysia).
1.3 Select parental lines for further crossing based on user-defined ideotypes (6-30 months; CFFRC to lead; Malaysia).
2.1 Test and evaluate core and 'local' germplasm for crop performance on multiple farm sites (6-24 months; CFFRC to coordinate and all participants to perform; Malaysia, Nigeria, Indonesia and Ghana).
2.2 Identify 25-30 lines with improved quantitative values for drought tolerance and cookability (shorter cooking time) (12-24 months; CFFRC to coordinate and all participants to perform; Malaysia, Nigeria, Indonesia and Ghana).
2.3 Test the best 10-15 candidate lines by expanded farmer trials (24-34 months; CFFRC to coordinate and all participants to perform; Malaysia, Nigeria, Indonesia and Ghana).
3.1 Utilise and develop an online platform for researcher networking and information and data exchange (continuously 1-36 months; CFFRC to lead; Malaysia).
3.2 Manage and guide overall project structure by on-site partner visits by lead institute (6, 12, 18, 24, 30 and 34 months; CFFRC to lead; Nigeria, Indonesia and Ghana).
3.3 Centralise, analyse, discuss, and organise the dissemination of research data and findings by all participants collectively (36 months; CFFRC to coordinate; Indonesia).
4.1 Coordinate capacity building by Partners for researchers from low income countries (12-34 months; CFFRC to lead; Nigeria, Indonesia and Ghana).
4.2 Coordinate capacity building by Partners for farmers from low income countries (12-34 months; CSIR-CRI to lead; Nigeria, Indonesia and Ghana).

<u>Activities 1.1-1.3; Output 1: Bambara groundnut PGRFA successfully conserved for further utilisation by farmers and researchers, allowing farmer-led selection of germplasm.</u>

The conservation of bambara groundnut PGRFA) will be coordinated by IITA, utilising their CGIAR genebank (headed by Dr Michael Abberton (MA)), extensive field space and researchers with substantial experience in germplasm characterisation. The development of an Association Genetics panel with single genotypes derived from known landraces, genebank accessions representing known species diversity, farmer and partner material is already underway in a collaboration between CFFRC and IITA. Single genotypes will allow a powerful genetic analysis, with the ability to reach back into the original landraces when suitable lines are identified. The panel will represent around 500 lines from genebank, farmer and other Partner material and will form the selection material for the current project. Previous co-dominant marker analysis (SSR; Molosiwa et al. IN PRESS) indicated residual heterozygosity of 0.02 on average (123 single genotype landrace accessions; 20 SSRs), making seed from a single plant essentially an unselected variety.

Activities 2.1-2.3; Output 2: Improved lines of bambara groundnut bred for drought tolerance and cookability, which are adapted to local environments, leading to more stable yields of bambara groundnut with shorter cooking times.

The breeding work for improving bambara groundnut for drought tolerance and cookability will be carried out by a linked cohort of PhD students at all participant institutions with oversight, assistance and direction from the hosting institution (CFFRC, IITA, CSIR-CRI, BAU, with sole or dual registration at the University of Nottingham Malaysia Campus (UNMC) as part of the CFFRC-UNMC Doctoral Training Partnership). Tuition fees will be covered by the institutions registering the student. Funds are sought within the current project for stipends, travel and consumable costs associated with the multi-locational research. As such, they will join the 40 current PhD students investigating underutilised crops as part of the multidisciplinary remit of CFFRC to diversify future agriculture through the use of underutilised crops, including eight students currently investigating bambara groundnut. The students will also be under the coordination of CFFRC/Dr Aryo Feldman (AF). PhD candidates will be sought with experience in plant breeding or training will be given by the Partners and project coordinator as needed.

Six-monthly visits by AF in addition to continuous remote communication with partners will ensure the overall project programme is delivering through already developed common protocols, germplasm and a field trial evaluation system. Farmer participatory trials will be carried out in the places of significant bambara groundnut production (IITA, CSIR-CRI, BAU). All three agricultural research institutes have their own farmer links and extension services for reaching them.

AF is a plant physiologist with plant- and farm- scale experience. He has designed and will coordinate the phenotyping and physiology analyses. Drought tolerance of specific genotypes (Activity 2.2) will be measured by crop responses to drought/irrigated field conditions (dry seasons) and minimal water requirement treatments in controlled environment experiments, in terms of growth, yield, chlorophyll content and fluorescence, and plant vigour, using the International Plant Genetic Resources Institute indicators (Attachment C), SPAD 5-2 Plus Chlorophyll Meter (Konika Minolta, Osaka, Japan), FluorPen FP 100-MAX (Photon Systems Instruments, Brno, Czech Republic) and GreenSeeker crop sensing system (Trimble, Sunnyvale, USA). More in-depth studies will look at root scans, photosynthesis curves and stomatal parameters in the final candidates. Cookability (Activity 2.2) will be assessed through direct physical measurements (the number of hours of boiling required to achieve an acceptable dish for the local consumers), penetrometer studies on fixed material with improved cooking time, alongside ultra-structural analyses to understand the basis of the trait. Initial screening will take place according to seed size and testa colour as smaller and lightly coloured seeds have anecdotally been reported as being correlated with shorter cooking times and a number of crosses segregating for these traits are available.

The genotyping will be designed and coordinated by CFFRC/Dr Sean Mayes (SM). SM has extensive experience in conventional genetics and molecular biology techniques as applied mainly to bambara groundnut, oil palm and wheat. Purified lines and crosses will be confirmed by fingerprinting using a sub-set derived from 103 SSR markers, developed by the University of Nottingham Sutton Bonington Campus (UNSB)/SM (Activity 2.2). Chromosomal regions/QTLs associated with the two traits of interest will be mapped using Genotype by Sequencing (GBS) (DArT Seq) using recently developed mapping populations between parental lines contrasting for the traits of interest (Activity 2.3). This GBS technique has been developed in collaboration with Dr Andrzej Kilian at DArT Pty, Ltd. (Canberra, Australia) as a long-term service for bambara groundnut and has been used in the construction of five genetic maps and an initial genetic diversity analysis. The genotyping system is freely available as a service to all researchers and we will work with the DivSeek initiative to ensure that all genotype datasets are forward and backward compatible, for independent researchers from developed and developing countries to be able to build upon the data results of this project.

Activities 3.1-3.3; Output 3: Information created, made available and actively disseminated on scientific and technical matters related to bambara groundnut PGRFA, including genotypic and phenotypic data

associated with specific lines, to provide materials for continued breeding development through researchers and farmers.

The researcher networking and information exchange for the project and its dissemination to the wider bambara groundnut research community will be organised by CFFRC, using their previously created dedicated online host site (BamNetwork, www.bambaragroundnut.org), website manager (Ms Razlin Azman) and the general management and administration team. The end of project workshop will bring together all Partners to consolidate findings, organise their dissemination and long-term availability to any interested parties. During the course of the projects, results will be made periodically available during the research programme through annual reports, seminar recordings, meeting presentations and manuscripts for international peer-review publications.

Activity 4.1-4.2, Output 4: Increased capacity of resource-poor farmers and researchers to characterise, conserve and manage PGRFA in Sub-Saharan African and Southeast Asian regions, which are particularly vulnerable to climate change, leading to the continual conservation and development of improved lines for farmers.

Capacity building of researchers will be managed by SM. He will make yearly visits to partner institutions to facilitate in the personal training of researchers, particularly in molecular support techniques for breeding and research work in addition to his continuous remote guidance. The development of robust and common standard operating procedures for marker data generation and for interpretation will form the core of the training. The selected researchers will also spend time at CFFRC's new research facility in Malaysia.

Capacity building of farmers will be carried out by partner institutions where bambara groundnut production and consumption exists at significant levels (IITA, CSIR-CRI, BAU). All three institutes have farmer extension services for training farmers and CSIR-CRI/Dr Joseph Berchie (JB) will be the focal point for the wider dissemination of training resources to farmers. He is the Regional Coordinator of the Research-Extension-Farmer-Linkage Committee (RELC) of the Ashanti region of Ghana, which is the second largest region in the country with the highest number of Districts. He also collaborates with other RELCs throughout the country.

2.4. Targeted PGRFA

The genetic resource input will be diverse bambara groundnut (*Vigna subterranea* (L.) Verdc.) farmer and partner landraces and single genotype accession landraces, genebank accessions (from IITA) and recently developed pure lines and controlled crosses (held at UNSB on behalf of SM) (in regard to Annex I of the International Treaty, bambara groundnut belongs to the Cowpea et al./*Vigna* category)

Two major clusters of genetic diversity in African Bambara groundnut have been previously identified and this information is being used as the basis for selection of the lines for construction of the Association Genetics panel, from which the lines for evaluation will be drawn (Massawe et al. 2002, Somta et al. 2011, Molosiwa et al. 2013, Molosiwa et al. IN PRESS). Pre-breeding work has already taken place, with a focus on plant habit, reduced photoperiod sensitivity and pod number (Aliyu et al. IN PRESS) and other traits consistently favoured by producers, processors and/or consumers. Also, the project will make use of extensive physiological data for novel lines and landraces developed during previous EU funded research programmes (BAMLINK (Attachment D) and BAMFOOD (Attachment E)).

Germplasm developed from this core resource during the project will be purified and lines with improvements in drought tolerance and cookability, alongside adaptive traits relevant to the local farmers, will be made available via research Partners. Information on potential parental lines identified will also be made available for other research programmes, including the CFFRC BamYIELD collaborative programme.

Basic characterisation (morphology, physiology and phenology) from evaluation of all germplasm will be made available as an open IITA resource. Dissemination of more detailed results will be published in print in peer-reviewed scientific journals and orally at international conferences/workshops/symposiums. The combined germplasm will be shared between partners for selections to be made, in addition to being conserved *ex-situ* in the CGIAR genebank at IITA for global public dissemination, in accordance with ITPGRFA's conditions.

2.5. Target groups and beneficiaries

This project's target direct beneficiary groups are researchers and small-scale farmers, and its indirect beneficiary groups are consumers and product processors, all from developing countries, and all within the scope of Partner extension and outreach services.

This is in addition to firstly to the training of researchers in running SSR marker analysis (activity 4.1): at least six in total (two from each Partner institution), who will pass on their training to at least six subsequent researchers (again, two from each Partner institution), although not necessarily within the project's completion. A second group of additional direct beneficiaries will be select farmers trained in pureline selection (Activity 4.2): at least fifteen core farmers in pureline selection. They would then work with Partner extension services and their farmer groups to train more farmers: 300 subsequent farmers, although not necessarily within the project's completion.

Feedback mechanisms are put in place for trainees to evaluate the teaching material to ensure its applicability on a wider scale. This will also be crucial as the success of training will be indicated by the ability of participants to carry out the project's activities.

In Ghana, the project could directly benefit ~1.6m bambara groundnut farmers (who are mostly (60%) women (Adzawla et al. 2014: Attachment A)) in the seven out of ten regions that mostly grow bambara groundnut: Upper East, Upper West, Northern, Brong Ahafo, Ashanti, Volta and Greater Accra Regions. The project could also indirectly benefit consumers (>3m; who are mostly (65%) women (Adzawla et al. 2014)), processors, researchers linked to CSIR-CRI and traders (who are mainly female), as well as students in basic schools who are fed under the school feeding programme.

In Nigeria, the biggest bambara groundnut producing country (>100,000 t/year; Hillocks et al. 2012), the project would directly benefit farmers (who are mostly (60%) women (Olayide 2014: Attachment B)). For a country with a population of 175m and where agriculture accounts for 70% of the main employment of the population, the improvement of bambara groundnut, the third most important legume in Sub-Saharan Africa after groundnut and cowpea, will have a marked impact.

Indonesia is a relatively recent producer and consumer of bambara groundnut. It is nevertheless an important target region, with bambara groundnut grown as a supplementary annual crop after rice during the dry season. In addition, Indonesia has developed a popular snack food, 'kacang bogor', and there is on-going work within the BAMYIELD programme with Indonesian research partners to evaluate a farmer cooperative model to producing this snack.

2.6. Impact and impact pathways

2.6.1. Food security and poverty alleviation

The impact of genetically improving resilience, i.e. drought tolerance, in bambara groundnut in the face of climate change will increase the security of a nutritious food supply. Farmer outreach will be scaled out by regional research hubs that will have additional capacity and materials through this project. These hubs have their own network of scientists, field and extension workers and are all long-term institutions, so will become the permanent regional centres of research activity, resource dissemination and farmer participation after project completion. In addition, it is expected that improving bambara groundnut germplasm in Ghana will benefit farmers, consumers and scientists in neighbouring countries, especially

those in the Sahelian countries who obtain bambara groundnut germplasm from Ghana. For example, the landrace, 'Burkina', which is prominent in Ghanaian markets originates, as the name suggests, from Burkina Faso (Berchie et al. 2010, 2012). Incidentally the same landrace is known as 'Ada' in the Coastal savannah agro-ecology of Ghana where it is also grown.

Opportunities for additional income generation by poor farmer families will be opened up by increasing/stabilising yields in poor years and also reducing the cooking time of the seeds, which will encourage consumer acceptability and so the crop's marketability. CFFRC and partner activities outside of this current proposal will investigate end-user, processing and value-added products for enhancing income generation and results will be made available through peer reviewed publications, the BamNetwork website and regional research hubs.

Newly improved genetic material will contribute to IITA's own seed bank, which holds the largest bambara groundnut collection (>1,800 accessions). All seed will be made publicly available with an emphasis on helping resource-poor farmers in compliance with the CGIAR mandate to serve national and international agriculture programmes. Many of IITA's breeding activities include considerable work with farmers (particularly women). This is also important for participatory end-user analysis to properly appreciate their preferences (e.g. quality, taste and cooking properties) and to build them into the various types of participatory selection and farm trials. The relationship between grower and breeder is hence sustained by an iterative feedback loop, which matches changing needs, e.g. challenges brought about by shifting climates, novel uses, and novel agricultural systems. Eventual (post-project) variety release is expected to also go through IITA's channels or through the relevant national agency for Partners. IITA's mandate for tropical agriculture allows them to work with national partners and perform extensive multi-environment trials on farmers' fields prior to seed dissemination.

In addition, scaling up the characterisation and evaluation of existing and newly developed germplasm, as well as the contribution to seed availability, will open up opportunities for local entrepreneurship and small seed companies. Associated and independent plant breeders will be able to register their own new and more marketable bambara groundnut varieties in partner countries based on the project's disseminated resources and tools (including training material). One of the aims of this project is to begin to establish a delivery chain from breeding to variety registration and release.

Having regional hubs in distant parts of the globe (i.e. Sub-Saharan Africa and Southeast Asia) links these two centres of genetic resources, scientific research and indigenous knowledge to allow for the free exchange of information, innovation and technology. Wider impact is therefore expected to benefit policy makers and government agencies, at the national, regional and global scales, in regard to adopting bambara groundnut and underutilised crops in general to address food security and poverty alleviation. This includes utilising the crop as a means of tackling iron deficiency and as a high protein source where animal protein is in short supply and/or expensive. In relation to other more common legumes like cowpea, lentils (*Lens esculenta*) and pigeon pea (*Cajanus cajan*), bambara groundnut has the advantage of already having more secure yields in periods of low precipitation and having a greater gross energy content: per 100g of seed, bambara groundnut = 390 kCal, cowpea = 343 kCal, chickpea = 364 kCal (de Kock 2004).

Bringing together these distant regions via the project is expected to promote further dialogue (formal and informal) and increased collaborative research output, during the project's lifespan and beyond. It is the intention of the project collaborators that research outputs will be disseminated to policy makers and other stakeholders. Specifically in regard to food security and poverty alleviation, stakeholders include national/regional development NGOs, farmer associations/organisations, consumer groups, ministries of agriculture and health, FAO, and WHO (as bambara groundnut is a suitable component of nutritiously diverse diets). Regular liaisons with stakeholders with interests in food security and poverty alleviation will get underway in 2018 via annual conferences, peer reviewed articles, websites, media engagement and direct contact. For example, CFFRC has contributed to Bioversity-run events, such as the biannual International Neglected and Underutilised Species conference.

2.6.2. Adaptation to climate change and environmental sustainability

This project empowers rural communities to adapt to climate change and increases the environmental sustainability of their agriculture by promoting bambara groundnut production either as a sole crop or, as is more commonly the case, as an intercrop with maize and sorghum in Africa, or as a rotation crop with rice in Southeast Asia. Recent surveys in Nigeria and Ghana (Attachments A and B) confirm that small holder farmers use both systems. Unimproved bambara groundnut already exhibits climate change resilience properties and demands little from the environment due to its drought tolerance, low soil nutrient requirements (as a legume, it fixes nitrogen) and its ability to grow on poor soils (e.g. with low pH levels).

The project's genetic improvement programme aims to enhance the drought tolerance trait while identifying material which is adapted to the local agroecology. Coupled with the development of reduced cooking time lines, this should address issues on both the production and the demand sides of the equation. Subsequent breeding targets will be identified through within-country interactions with farmers, markets and end-users. Working links will be made with national and international stakeholders, and funding agencies to secure the financial resources to make this crop improvement pipeline sustainable. This will also be important for enabling the adaptation to new opportunities and response to new threats, such as climate change. The network of research hubs developed allows the scaling out to more plant breeders and for farmers to select lines and identify new ideotypes for breeding work, for their own particular agro-environments and needs, e.g. certain farmers may require seeds that have a shorter growing cycle due to climate change induced shortening of the growing season.

Connecting the two dispersed regional hubs provides the potential to scale out the beneficiaries from the national scale to the regional and even international scales. There are few examples of the development of coordinated research and participatory farmer action across continents. The successful learning process from this project will allow other underutilised crops to be addressed at a similar scale. It is expected that through the realisation of their potential, underutilised crops will find a place in national strategies to address climate change and environmental sustainability, such as NBSAPs, to affect policies. The importance of biodiversity and underutilised crops in combating climate change has been continuously addressed (e.g. Burke et al. 2009, Lobell et al. 2009) and the project's relevant activities such as capturing the genetic diversity in bambara groundnut (Activity 1.1) will contribute to this. Scaling out impact to a more global scale can occur once links are formed to international/CGIAR centres like CCAFS (Climate Change, Agriculture and Food Security) and CIFOR (Center for International Forestry Research), which is located in Bogor, Indonesia.

2.6.3. Scientific impact

A major scientific output of this project, the germplasm wide characterisation in multi-site locations, will be an unprecedented scaled up collection of scientifically robust, reliable and comparable data on crop analysis of bambara groundnut, alongside an available panel of 500 genotype lines (with linkage to original landrace; currently in development) and detailed comparative analysis of a core set of 20 lines, with predictive selection of a further 20 lines for specific environments, using common protocols. This alone will boost the crop in terms of scientific credibility, e.g. in regard to publications in international peer-reviewed journals. This will also result in the high quality presentation and dissemination of results to the wider scientific and non-scientific (e.g. donor) circles. Currently available information on bambara groundnut is often limited and somewhat fragmented. This is due to the lack of communication and collaboration between researchers, and limited, unsustained funding. Furthermore, most previously gathered data is from local germplasm, in national environmental conditions and focuses on local problems and solutions, preventing the development of a strong body of comparable research data. Working with the CGIAR system (i.e. IITA) helps to ensure that all information is made publicly and freely available, for the long-term.

The attempts to genetically locate traits of importance will also be novel in this crop and will allow the development of integrated marker assisted selection in breeding new variants. As an example, we have

recently localised the major gene affecting photoperiod requirement for pod-filling (manuscript being written) in many landraces and will use flanking markers to select seed from crosses expected to be less photoperiod sensitive. The same approach will be used for drought tolerance and the reduced cooking time character components.

The application of socioeconomic approaches to data analysis, such as the qualitative data analysis software, NVivo (version 10), represent non-conventional ways to analyse scientific data. Such approaches allow the development of different perspectives on journal, PhD, report and grey literature. BamYIELD is currently coding all available literature for Bambara groundnut into NVivo to develop a tool for evaluating knowledge gaps and required research (Halimi et al. 2013), which will underpin partnership activities.

BamNetwork, the open-source online platform for the bambara groundnut research community, will ensure that the project's relevant data is retained and scaled up after project completion. It is anticipated that the project data will provide much of the necessary groundwork for further and more detailed analysis (i.e. scaling out and up of scientific data), by adapting the tools and translating the knowledge and information from research on major crops, using sequence-based linkages developed from Bambara groundnut to related legumes with full genome sequences. CFFRC is also involved in the African Orphan Crops Consortium/World Agroforestry Centre/Mars 100 Orphan Genomes project (http://www.mars.com/global/african-orphan-crops.aspx), so a genome sequence for bambara groundnut is expected in a few years.

.

2.6.4. Capacity development and empowerment

Researchers trained in genetic fingerprinting will gain an essential skill that will remain relevant and can be applied to any crop. Farmers trained in pure-line selection will acquire a tool that empowers them to adapt to changing circumstances, such as climate shifts. The capacity development of long-term research hubs for bambara groundnut will ensure continued research and breeding activity beyond the end of this project. In addition, the conservation and evaluation of existing local and international germplasm, as well as novel lines, will make more material available for farmers and researchers to continue to utilise their training in breeding techniques. The core trained group of researchers and farmers will be encouraged to train further people in country and we will work with Partners during this project to secure additional funding to do this. IITA, for example, engages extensively with national agricultural research systems (NARS) and extension services. They have a Partnership and Capacity Building Directorate which develops collaborations that often involve extension and farmer groups, as well as the private sector.

The scaling up of skills and capacities gained by researchers will be utilised and sustained after project completion. The development and maintenance of the project's network of international crop research partners that are able to carry out high level research on any underutilised crop, as bambara groundnut is representative of underutilised crops as a whole, will facilitate the dissemination of important results, resource sharing and the formation of new collaborations. In addition to institutional links, this will be supported by the online BamNetwork. Part of BamNetwork's capacity will be an FTP service for storing data, publications and other online resources, and disseminating them to registered users for free, focusing on open access publications where at all possible.

An important example of this is the development of generic field trial designs that will be applicable to other crops, especially in regard to underutilised species and their associated bottlenecks. Participants in the project's network and those associated in the resulting value chains will therefore be equipped to initiate their own genetic improvement programme for their own crops of interest, which are anticipated to be mainly indigenous and neglected ones.

2.7. Relevance to national or regional priorities in its plans and programmes for PGRFA

The conservation of bambara groundnut PGRFA- local farm landraces, recently developed lines and germplasm developed during the project- contributes directly to national priorities of participating

countries to food security in the face of climate change. All participating countries include governmental mechanisms for adapting to climate change through PGRFA. For example, there is a National Adaptation Strategy and Plan of Action on Climate Change for Nigeria**,** which includes strategies for biodiversity in agriculture. This is covered by their National Biodiversity Strategy and Action Plan (NBSAP). In its latest report (Fifth National Biodiversity Report: Attachment I), explicit reference is made to bambara groundnut in the conservation of agro-biodiversity. Ghana, Indonesia and Malaysia are also parties with NBSAPs, making special references to agro-biodiversity, though without explicit mention of bambara groundnut.

Non-governmental nationwide initiatives also promote bambara groundnut PGRFA for adaption to climate change and food security. The Community, Seed and Knowledge initiate in Ghana has worked with Regional Advisory Information and Network Systems to conserve indigenous crop material, including of bambara groundnut.

IITA have contributed bambara groundnut seed to the Svalbard Global Seed Vault and so contributions to genetic conservation and germplasm development from the project could have an effect on PGRFA on a world-wide scale. The International Assessment of Agricultural Knowledge, Science and Technology for Development makes clear the urgent need to invest in both PGRFA and domestic small-scale agriculture systems. These systems are the most suitable for bambara groundnut production and are seen as vital for national food security when faced with domestic and global food price volatility. Volatility is linked to a range of factors including poor harvests due to climate change disasters like large-scale floods and droughts. The other important aspect is the ability to use marginal land (and low input agricultural systems) effectively. Continued growth of major crops on marginal soils is not sustainable and a transition to more sustainable crop options is needed, leading to the replacement of those major crops in certain regions as climate change develops. In Malaysia, Bambara groundnut grows and yields well on ex-oil palm estate land (pH 4.2) which are highly degraded soils.

SECTION C: OPERATIONS

3.1. Methodology of project implementation

The direction or narrative of the project is reflected in its logical framework (Appendix 2), workplan (Appendix 3) and budget (Appendix 4). All work in unison to ensure for achieving project outputs.

Project design and execution follows a scientifically-proven and systematic approach, taking the lessons learnt from the multi-national, EU funded BAMLINK and BAMFOOD projects (Attachments D and E). The project has four outputs implemented to address the reduction of extreme poverty and hunger and ensure environmental sustainability by improving adaptation to climate change and enhancing the food security of resource-poor farmers in selected developing countries, by strengthening the sustainable management of PGRFA:

Output 2 follows from Output 1 as it supplies the genetic material for trait analysis and improvement. Resultant data and findings from Outputs 1 and 2 will be the continual source of data for knowledge handling, i.e. Output 3. Capacity building in Output 4 will also be concurrent with Outputs 1 and 2 as it will help to ensure that these two objectives are embedded for long-term capacity building. This is illustrated by the workplan Gantt Chart (Appendix 3).

Output 1 will be carried out according to IITA's well-established practices for *ex-situ* and *in-situ* genetic conservation. Output 2 will be determined by CFFRC, whose staff members (including SM) have been instrumental to setting up bambara groundnut breeding programmes in the BAMLINK project (Attachment D). Output 3 will be managed by CFFRC and Partners with the online network of bambara groundnut researchers (BamNetwork) and other developing knowledge programmes at CFFRC, such as CropBase. In addition, all senior staff have extensive (25+ years) experience writing for international peer-review scientific journals and presenting at major conferences/workshops/symposiums. Output 4 will be coordinated by CFFRC and carried out by partner institutes (IITA, CSIR-CRI and BAU) as each have their own team of extension workers and farmer outreach programmes, in addition to being in countries of significant bambara groundnut production and consumption.

CFFRC will take the lead in managing the institutional capacities and expertise that are most relevant to each output. All partners have formally agreed to their respective responsibilities. MOUs have been signed between CFFRC and both IITA and CSIR-CRI (Attachments I and J). The MOU between CFFRC and BAU is currently being agreed upon and a letter of intent has already been signed. A common field trials protocol has been collaboratively developed between all partners (Attachment J). A Project Management Committee (PMC) including the PIs at each Partner will be established to oversee and coordinate the implementation of the Project. The PMC will meet as often as needed to establish the project and will then meet at 2 month intervals. A Science Research Committee (SRC) including the senior research personnel at all of the institutions who are actively involved in the research project will be established and will have meetings every two weeks via Skype, in addition to when particular issues arise. Most activities have been validated in previous projects and those approaches and techniques that are novel will be pilot tested by CFFRC and Partners before full-scale implementation. CFFRC will therefore manage the collaborative mechanisms through support and guidance from experiential learn

3.2. Partnerships and collaboration arrangements

The project’s consortium of collaborators will come together to solve a similar problem being faced in different developing countries that are also Contracting parties to the Treaty: nutrition and income security in low income, low resource regions that are vulnerable to the detrimental effects of climate change related drought. The consortium also addresses a more global problem of the low level utilisation of bambara groundnut despite its potentially major benefits to the farmer, market, consumer and environment.

The consortium includes national partners of the beneficiary (CSIR-CRI and BAU) and international partners located in countries of the beneficiary (IITA and CFFRC) that have complementary technologies and information, and are operating large-scale research and data hubs and repositories. The partners in the consortium will work together in the co-development and utilisation of technologies that enable the utilisation of PGRFA for the generation, exchange and utilisation of molecular, phenotypic and genotypic information.

Consortium members have complementary capacities and expertise to carry out specific active and constructive roles. CFFRC is the only international centre solely focused on underutilised crops, such as bambara groundnut. It brings in experts in diverse disciplines from around the world to research the entire value chain from production through processing and onto consumption. Such experts include plant researchers with 20 years of experience working with bambara groundnut (e.g. the CEO, Sayed Azam-Ali). CFFRC also has strong links with other institutes from around the world that have top class facilities and scientists (e.g. UNSB and DArT Pty Ltd, Canberra, Australia) for outsourcing research components. IITA's long history as a CGIAR centre means that it has the extensive facilities and personnel necessary to carry out large scale genetic conservation and evaluation. CSIR-CRI is heavily involved with local farmers and government agencies so has the capacity to translate research outcomes to the national and potentially West Africa regional scales. BAU is the top national agricultural research centre in Indonesia and so has a similar capacity in the Southeast Asia region. All four institutes have a long history in plant breeding, including for bambara groundnut, which is the crux of the project.

3.3. Project management team

The project structure will consist of two regional research hubs, one in West Africa (directed by JB) the other in Southeast Asia (directed by Prof Satriyas Ilyas (SI)), with CFFRC taking the role as overall project coordinator, disseminating resources, knowledge and technology. Hub directors will have the responsibility of ensuring research outputs reach local target communities. The CFFRC team are members of the broader BamYIELD programme. BamYIELD's research focus is on bambara groundnut with a proven track record: including over a dozen conference presentations and papers within the past two years, with four international journals papers published or in press. He has worked in project management since 1989 and has supervised 25 PhD and ten MSc projects. It is an established unit of three researchers, including SM as the director. His expertise as principal investigator will determine the proper guidance and execution of the project. He has a proven track record of developing international research network links, having worked with four African countries, six Asian countries and three European countries. AF is the BamYIELD programme coordinator and will be responsible for the planning, management and data handling side of the project, ensuring that the research is being properly supported and conducted every step of the value chain. As BamYIELD programme support manager, Ms Razlin Azman will execute the administrative tasks, as well as provide intellectual and other crucial resources. As well as managing the BamNetwork site, she has compiled all available research papers on bambara groundnut and generated its metadata using qualitative data analysis software, NVivo (version 10).

3.4. Sustainability

BamYIELD is the overarching programme with which this project is associated and is a core component of CFFRC's research activities. The infrastructure and staff costs of CFFRC are guaranteed by the Government of Malaysia until the end of 2017. This ensures personnel and facility costs, although funding specifically for research is not included.

The inclusion of regional hubs has the advantage of linking the target groups to the central structure through their own networking systems. These partnerships have already been solidified and will serve as the conduit through which scientific research will be translated through to farmer trials during the completion of the project. Early engagement with target groups through representatives of farmer organisations will support the sustainability on-going implementation of project activities, evaluation of

outputs and outcomes and ensures that farmer's priorities are addressed within the breeding programme. This will be backed by regular fora with stakeholders, such as government agencies and development oriented NGOs.

A system of collaboration and experimentation will be established that can be used for future approaches to major funders on the basis of a functional consortium, top quality research and released varieties. Establishing the network of institutions from low income countries as international level research organisations is intended to empower such organisations to be leaders in future research. It will also make it easier for future bi- and multi- lateral links between partners, which is essential for building up the human and institutional support for conducting international research.

SECTION D: APPENDIXES

By signing this submission form for full proposal, the applicant confirms that all the above statements, including the attached Appendixes, are true to the best of his/her knowledge. Any deliberately untruthful response will lead to the automatic exclusion from the further screening and appraisal process, and may lead to the denial of awarded grants from the Benefit-sharing Fund.

Signature of contact person:

Date and location: Friday 5th December 2014, Semenyih, Malaysia