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Synergizing fertilizer micro-dosing and indigenous vegetable production to enhance food and economic security of West African farmers

(CIFSRF Phase 2)

MicroVeg Project Number 107983

Location of Study: Nigeria and Benin Republic By

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1.1. Executive Summary:

The original goal of this MICROVEG project was to investigate the synergy of fertilizer micro-dosing and indigenous vegetable production innovations to enhance food and economic security of West African farmers**.** We have chosen this line of research because the agrarian, rural and resource-limited across Africa depend on indigenous edible vegetables for daily supplies of vitamins and nutrients. Despite their importance for food and nutrition security, these indigenous vegetables had not been a subject of organized research, from production to value addition. Therefore, the MicroVeg story extends from innovation in field production practices including fertilizer microdosing and optimum water management to innovation in food processing and value addition, hence our slogan is "From Farm Plot to Household Plate" (Plate 1). During the last 36 months, our team (MICROVEG Project) conducted innovative biophysical and scaling up research and public awareness and is pleased to present the following Key "take-

away" messages from this study (Project 107983). More detailed information is available in the task team reports that are presented as highlights in Section 3 of this report:

General and marketing information:

- Female vegetable farmers are older than their male counterparts with an average age of 46 years and 50 years for Benin and Nigeria, respectively. The majority of male and female vegetable farmers are middle-aged with an age range of 31-55 years.

- The level of formal education (88.9%) among female vegetable farmers is higher than the level of formal education (80.5%) among male vegetable farmers in Nigeria. In contrast, the level of formal education (40.0%) among male vegetable farmers is higher than the level of formal education (14.0%) among female vegetable farmers in Benin.

- Indigenous vegetables (IVs) marketing in both Nigeria and Benin Republic is predominantly female dominated with over 90.0% female participation in both countries. Whereas marketers in Nigeria are relatively older and have up to 12 years formal education their Benin counterparts are younger with fewer years of formal education.

- IV marketers in both countries do prefer to market a variety of vegetables species including both indigenous and exotic vegetables.

Consumption and profitability of IVs:

- In Nigeria, the per capita consumption/annum of *Solanum macrocarpon* (Igbagba) is about 25 kg while that of *Telfairia occidentalis* (ugu) and *Amaranthus viridis* (tete) are 37.5 kg and 44.7 kg, respectively while in Benin the per capita consumption is about 25 kg for *Amaranthiss* and 30 kg each for *S. macrocarpon* and *Ocimum gratissimum* (Tchiayo). It is estimated that average of 80% of the population (120 million in Nigeria and 10 million in Benin) consume these vegetables in the two countries.

- The revenue obtainable from the marketing of IVs in Nigeria increased by about 119.7% over the project period (36 months) and that of Benin Republic also increased by 90.1%. This shows clearly economic advantage by the participants who are mainly female and confirms the empowerment motive of the intervention.

- The total variable cost incurred on each $6m^2$ plot at 0 kg, 20 kg, 40 kg, 60 kg and 80 kg Urea-N/ha were \$2.94, \$3.32, \$3.34, \$3.37 and \$3.42while the total incomes were \$23.65, \$40.51, \$45.89, \$61.08 and \$39.52, respectively**.**

- Vegetable production based on 0.5 ha land area resulted in a net revenue of \$3,879.00 and \$3,650.00 in Benin and Nigeria, respectively. Benefit cost analysis revealed that every \$1 invested in vegetable production generates a return of about 0.8 cents in Benin and 0.5cents in Nigeria.

Agronomic investigation:

- The average fresh leaf yields of the four vegetables increased from 1.3 and 3.2 kg/m² under control (no fertilizer) reaching a maximum of 2.6 and 6.5 kg/m² under 60 kg/ha of urea-N application in Benin and Nigeria, respectively. A contributory factor to this yield increase is the basal application of organic manure at a minimum rate of 5 t ha^{-1} to sustain the soil productivity.

- Partial nutrient balance computation (nutrient input minus vegetable leaves nutrient uptake) showed that continuous vegetable (*Solanum, Telfairia, Amaranthus* and African basil) production without manure depleted the soil in N (-268.3 to -30.8 to kg/ha for D40, -195.0 to -4.5 kg/ha for D60), P(-65.0 to -18.3 for D40 and –286.0 to -18.7 kg/ha for D60) and K (-336.3 to -2.3 to kg/ha for D40, -2703.2 to -2.4 kg/ha for D60), although soil nutrient mining was moderate with African Basil.

- The combined application of fertilizer micro-dosing and manure (5t/ha) in continuous production during one year of *Amaranth* (4 cycles), *Telfairia* (one cycle), *Solanum* (2 cycles) and African Basil (2 cycles) led to a positive N balance under Amaranth (+60.8 kg/ha for D60) and African Basil (7.4 and 33.8 kg/ha for D40 and D60 respectively). K and P mining is avoided only when manure (5t.ha) is renewed at each crop cycle or higher amount is applied instead.
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- When fertilizer microdosing is combined with 5 tons of organic manure, our results showed that the residual macronutrients in the soils after three cycles of vegetable harvest were not significantly different from the traditional fertilizer applications method. This shows that fertilizer micro-dosing can be used to sustainably produce these vegetables when combined with organic manure at the rate of 5 t per ha.

- The average water use by the vegetables in each crop cycle (dry season and rainy season) ranged from 285 to 377 mm in the forest and savanna agro-ecologies, respectively. Fresh biomass yield was an average rate of 31 kg ha^{-1} per 1 mm of water used in the rainforest, while in the dry savanna it was average rate of 27 kg ha^{-1}. The water required to produce one kg of Amaranth was reduced from 450 L on the traditional irrigation method to 200 L under capillary irrigation that we developed. This translated to water saving of approximately 2.2 million L/ha and 8 million L/ha in the rainforest and savanna ecosystem, respectively.

Food science and value addition investigation:

- We developed low-cost (~$12/unit) sun-driers and charcoal-powered ovens as a means of converting fresh leaves into dried leaves with storage or shelf-life of 12 months. Drying was completed within 4-5 hr and dried leaves reconstituted with water for use as regular soup ingredients showed acceptability that is consistent with that of fresh leaf soup. Seventeen (17) drying units were installed and used by farmers in Nigeria and Benin. These local technologies can be readily adopted in

rural areas.

- We developed new technology on packaged boiled-frozen vegetable leaves that have been taken up by third parties who are now using the existing distribution channels for fish and meat marketers to provide access to refrigerated and frozen vegetables in Benin. We are glad to report that more than 600 distribution points were contracted by the project to market the frozen vegetable product.

- We developed a protocol for vegetable polyphenol extraction and we successfully utilized the polyphenol for fortification of local foods, juices and pastry products. The fortified foods were also evaluated for sensory properties and consumer acceptance. Indeed, the popularity and acceptance of the green bread have been greatly enhanced such that it now features prominently as part of the diet of many people within the Obafemi Awolowo University campus, Ile-Ife, Osun State, Nigeria. Also, the overall acceptability of other fortified foods and beverages was very similar to those of the control products. The vegetable-fortified pineapple juice has been on sale in bottles and test-marketed in several local Cotonou and Parakou stores with great success, which supports consumer acceptance and a promising commercial impact.

- We demonstrated the ability of the polyphenol concentrates to reduce blood pressure and also inhibit digestive enzymes, such as α-amylase, α-glucosidase, and pancreatic lipase related to obesity and diabetes. Especially active were the polyphenol concentrates from *Telfaria occidentalis* and *Amaranthus viridis*, both of which reduced the blood pressure of spontaneously hypertensive rats (SHRs) by up to 40 mmHg. Test in human subjects will be next subject of research, if we are able to secure additional funding. This opens the possibility of developing a variety of nutraceutical products and also patent for our research effort.

- Our research showed that using the standard conversion for rat to human dose, a typical 70 kg man or woman will require ~1 gram of the polyphenol concentrate from from *Telfaria occidentalis* and *Amaranthus viridis* per day for efficient blood pressure reduction. This polyphenol concentrate dose is equivalent to the consumption of 21 grams of fresh leaves on a daily basis, which can be readily achieved based on food consumption patterns in West Africa. However, the key message to the population is regular (daily) consumption of this amount of leaves in order to benefit from the blood pressure-lowering ability. If regular consumption is not feasible in some instances, then supplementation with the polyphenol concentrate either as a powdered drink (the product is highly soluble in water) or added to beverages. For some part of the population, intake of the concentrate in the form of nutraceutical capsules alone or in combination with vegetable leaf consumption may be the most feasible route to obtain antihypertensive benefit.

- Vegetable fortification also led to extended shelf life of some of the food products; for example, *Chin-chin* and green-bread stayed fresh 2-3 days longer than the regular white bread. The extended shelf life is attributable to the presence of

antioxidant polyphenols, which would reduce the need for use of synthetic antioxidants in such wheat-based products.

Efficiency of scaling up models, YVSC and training:

- MicroVeg Project utilized two major scaling up models: the **Satellite Dissemination Approach (SDA)** and the **Innovation Platform (IP)**.The hypothesis behind the **Innovation Platform Approach** is that cooperation among stakeholders and actors enhance adoption and scaling up while **Satellite Dissemination Approach** relies on information and capacity building (training, demonstration, information, etc.) to reach the same goal.

- The scaling up objective of the MicroVeg project was achieved through the professional and technical support of the five NGOs (The Green Generation, The IAR&T, Alpha Omega Environnement AOE, Association pour la Recherche et la Promotion en Pisciculture Intégrée AR2PI and ZACOZA-ONG) that were recruited since the inception of the project. The NGOs played significant role in active development of the outreach, awareness creation, and organization of meetings, extension and negotiations. These key activities that were shouldered by the NGOs ensured the success of the scaling up of vegetable technologies to reach and exceed the targets.

- The innovation platform (IP) approach proved to be more effective for scaling up innovation than Satellite Dissemination Approach (SDA). We showed that involvement of many actors along the vegetables value chain, through the Innovation Platform (IP) enabled MicroVeg to understand issues of concerns in the entire value chain. A comparative analysis (2015 vs 2018) of the level of concerns between male and female farmers around the indigenous vegetables value chain showed that with MicroVeg's IP intervention, the gap between men and women farmers was reduced drastically.

- The project exceeded the number of 255,000 farmers planned for the project period. Over a 36 month, our project reached a total of 337,931farmers (50.6% female). The total number of farmers (vegetable producers) reached in Nigeria is 229,750 (51.6% female) while in Benin, 108,181 farmers (46.3% female) were reached through both scaling up models, SDA and IP.

- In Nigeria, as of March, 2018 the majority of the actors on the IPs were vegetable producers (229,750) (51.5% female) while in Benin, producers are 108,181 (46.3% female). Vegetable marketers (21,528) (71.2% female) in Nigeria while in Benin, vegetable marketers (6,948) (72.2% female). Vegetable processors were 561 in Nigeria and 12,562 in Benin with 62.5% and 98% female, respectively while extension service officials were 945 in Nigeria and 65 in Benin with 52.4% and 21.5% females respectively. Seed suppliers were 478 (48.1% female) in Benin while in Nigeria, seed suppliers were 140 (32.1% female). Least

actor was recorded for the transporters with 1.3% female in Nigeria and 0% female in Benin.

- As a result of our scaling up activities, within 36 months of MicroVeg project intervention, land area under vegetable production in Benin increased from 985 ha to 2,575 ha representing 161% increase while land area under vegetable production in Nigeria increased from 9,105 ha to 79,110 ha representing 768% increase. Currently we have at least 80,000 ha under cultivation with indigenous vegetables in the two countries.

- We integrated 181 secondary schools (124 in Nigeria and 57 in Benin) into MicroVeg Project Young Vegetable Scientist Club (YVSC) and we trained them in vegetable science and production technologies. We also trained 957 teachers made up of 881 teachers (46% female) in Nigeria and 76 teachers (38% female) in Benin. We are glad to report that there was no YVSC in the schools at the take-off of our project but we established these clubs and we reached 82,713 students (51% female) in Nigeria and 30157students (41% female) in Benin. The YVSC is now part of policy in the schools' curriculum of activities.

<u>Policy impact and private sector involvement:</u>

- We established a very robust relationship with policy makers and governments through some of our innovative strategies. For example, we integrated 10,000 youth of the OYES programme of Osun State Government into the vegetable value chain and majority of them are now successful vegetable producers. MicroVeg is recognized by Government as a result of this intervention. We also integrated 600 inmates at the Ilesha Prisons into the production stream and they are now producing their own vegetables. The Nigerian Prison Service recognized MicroVeg for this intervention. Our YVSC also made significant impact on policy because Ministry of Education was involved and this led to the inclusion of MicroVeg in the weekly schools' curriculum. We also succeeded with the inclusion of Ministries of Agriculture through the direct role played by their officers at our several scaling up meetings. These are major activities with potential to influence policy on a wider scale.

- In Nigeria, to ensure unhindered credit sourcing for vegetables value chain actors, our project initiated and signed MoU with the private sector- LAPO Microfinance Bank (MfB). MicroVeg negotiated the interest rate on the loans and the repayment period with the LAPO MfB. Loans are to be repaid between 6-12months at an interest rates of 3.6% monthly (other bank loans in Nigeria attract at least 19% interest rate) with repayment to commence at the end of 60 days after release of funds and an incentive of a 40% draw back on interest for farmers who complete loan repayment by the end of the loan duration.

- MicroVeg facilitated the negotiations with LAPO MfB with farmers in attendance and today we are pleased to report that as at March, 2018, LAPO MfB has provided a total loan of NGN13 million (US$37,142) for vegetable production to our farmers.

- Also in the area of policy, our project has established direct links with the Standards Organisation of Nigeria (SON) and process has begun to establish the NIGERIAN STANDARD for green pastry products which had not existed before now. SON has also commenced the process of formulating policy to hasten certification of such manufactured products in Nigeria. In Benin Republic, the project has established a partnership with the Direction de l'Alimentation et de la Nutrition Appliquée (DANA) to commence the process of certification of the value added products.

- In Benin, marketing posts have been established at University of Parakou (UP) and University of Abomey-Calavi (UAC), as a key activity of university YSVCs and sales of fresh, value added vegetable take place every Tuesday and Friday on campus. The Obafemi Awolowo University, Ile-Ife has approved the marketing and sales of green bread on the campus. Marketing of bread fortified with 3% vegetable was introduced to the Obafemi Awolowo University community in February 2017. Consumers welcomed the bread and sale has improved tremendously.

GIS and Synchrotron studies:

We developed an online GIS-based reference map http://webgis.usask.ca/microveg/ and a profit calculator (http://webgis.usask.ca/microveg/newProfitCalc.html) to estimate fertilizer and water needs as well as profitability for any site in Benin Republic and Nigeria. The maps and calculator were developed based on our project results and feedback from PIs and extension agents.

- We performed Synchrotron-based research on sustainability of MicroVeg technology using the Canadian Light Source (CLS) and used the results to infer the sustainability of MicroVeg practices on soil health. We found that the forms of carbon (C) depend upon ecoregion rather than the vegetable choice or fertilizer application, implying that this element is not strongly affected by MicroVeg practices over the time frame of this project.

- Through our Synchrotron research, we found that the forms of soil nitrogen (N) are strongly influenced by the MicroVeg inorganic fertilizer input. We observed decreased total N levels in MicroVeg plots compared to manure-only samples, but the organic forms of soil N had shifted from decomposed forms into more protein-rich forms. This suggests that MicroVeg additions are increasing plant biomass and yields, and inorganic N is cycling and will be available in the seedbed.

- Through Synchrotron studies, we also found that Phosphorus (P) had some initial dependence on ecoregion, with soils from the Sudano-Savannah being higher in calcium phosphate before planting. However, the major changes in available P are due to a combination of N fertilizer addition and the choice of vegetable. These results suggest that later harvests of *Amaranthus* could benefit from a side-dress NPK application.

Impact of communication strategies and training of students:

- One of our communication strategies *"Ramo Elefo"* radio programme which reaches an estimated 10 million people daily, was categorized as "very helpful" by most (63.5%) of the respondents (880) to inform their activities on vegetable value chain. Also, 62.3% of the respondents who saw the programme as relevant were females.

- We organized the first international conference on indigenous vegetables in Africa (Cotonou, Benin Republic in November 2017). One of the goals of this conference was to bring together the stakeholders in the indigenous vegetables value chain. The conference focused on development of improved agronomic methods, improved value addition, post-harvest and processing technologies, financing and the development of new market outlets which would contribute to the economic well-being of the rural women and generally enhance the average family income and provide a bulwark against food and nutritional insecurity. A total of 11 countries, 79 researchers, IDRC and GAC attended the conference. . The proceeding of the conference is in the final editing stage by the International Society for Horticultural Science to be published in Acta Horticulturae (*https://www.actahort.org/*).

- The statuses of studentship of the MSc and PhD students who were engaged by MicroVeg project is presented as Appendix 12. We are glad to report that we have graduated one (1) PhD, 15 BSc students and 8 MSc students. Additional 12 MSc and 3 PhD students will complete their programmes in 2018.
- We are glad to report that in the last 36 months we have published 23 peer reviewed high impact journal articles, and 07 others are under-going review at the journal level. We made over 30 television appearances in addition to our daily radio jingles. We published 5 newsletters and bulletins. Our website is also highly patronized by the international community, reaching 25,640 visitors in June 2018. We presented over 30 papers at international conferences. Beside the 16 conferences papers that have been accepted for publication in *Acta Horticulturae*, a batch of more than 20 papers are in preparation for submission.

In summary, we have researched the resource and production issues, provided new and innovative fertilizer microdosing and water management practices, developed new science on polyphenols and food fortification, successfully introduced new IV-based food products to the market through awareness creation, advocacy, training and gender equity analysis, and proposed potential new agri-business and job opportunities through this IDRC-GAC sponsored project. Collectively the Teams have provided a conclusive "proof of concept" that IVs can be economically and sustainably produced, processed and marketed to improve the diversity of foods and nutrition as well as incomes for resource-limited women farmers, their families and rural communities in West Africa.

Plate 1: Summary of MICROVEG project, indigenous vegetables for food and income security and dietary diversity.

2.1. Research problem

The agrarian, rural and resource-poor inhabitants of Nigeria and Benin depend on indigenous edible vegetables for daily supplies of vitamins and nutrients. Despite their importance for food and nutrition security, these indigenous vegetables had not been a subject of organized research, therefore, this research project was initiated to develop new technologies to improve farming practices, post-harvest handling and value addition for these indigenous vegetables. This offers numerous opportunities for food security and economic empowerment of the poor rural population, especially resource-poor women farmers. This project is a synergy of the Nigeria-Canada Indigenous Vegetables Project (NiCanVeg Project 106511) (https://www.idrc.ca/en/project/sustainable-production-underutilized-vegetables-enhance-rural-food-security-cifsrf) and the Integrated Nutrient and Water Management in the Sahel (INuWaM Project 106516) (https://www.idrc.ca/en/project/integrated-nutrient-and-water-management-sustainable-food-production-sahel-cifsrf). The promising results of the innovations that were developed by the two projects are being explored for complementarity to accelerate large-scale adoption and impacts of underutilized indigenous vegetable and fertilizer micro-dosing innovations to increase food and nutritional security and economic empowerment of resource- poor farming communities in Nigeria and Benin. The project has developed, tested and deployed two approaches for scaling up fertilizer micro-dosing innovations to improve production. We were set to reach over 255,000 households. This project goals were:

- Refining and deploying technologies for fertilizer micro-dosing, water management, value addition and seed production for growing indigenous vegetables.
- Testing, demonstrating and deploying two different models (Innovations Platform IP and Satellite Dissemination Approach SDA) for reaching and benefiting more

farmers with sustainable vegetable production and marketing innovations.

- Scaling the ***capsule technology***** to advance indigenous vegetables production, increase yields and income through value addition, preserve soil and water ecosystems, and enable fertilizer cost saving.
- Promoting policy advocacy for the integration of the successful scaling up model into local, national and regional food security programs in West Africa

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****Capsule of technology*** refers to a set of best practices that are used in combination to take advantage of technical complementarity for optimum benefit. In the case of this project, for example, a capsule of technology refers to optimum practices including planting spacing, seeding population, fertilizer rates and water management to produce optimum fresh leaf yield of vegetables.

3.0 PROGRESS TOWARDS MILESTONES:

It can be noted that all the milestones planned for the 36 months have been achieved. All the various project activities that relate to each milestones are discussed below.

Milestones	**Key Accomplishment**	**Deliverables**
Inception workshop	Project Inception Workshop was successfully held on the campus of Osun State University, Osogbo, Nigeria between May 23 and 30, 2015. There were 54 scientists, 21 farmers, 16 extension officers, 4 policy makers in attendance. National project launch workshop (July 2nd, 2015) in Parakou, Benin.	Report submitted as Appendix to First Interim Technical Report (September 2015). Report was accepted.
Performance Measurement Framework (PMF) for the study	A description of the project Logic Model and Performance Measurement Framework was developed	The fully developed report was submitted as Appendix to 3rd Interim Technical Report. Report was accepted.
Research Implementation Plan	The Research Implementation plan include all the protocols for each section of the project.	All the plans were submitted as Appendix to 2nd Technical Report.
Gender Equity Assessment Framework	The gender equity assessment framework (GEAF) was developed.	The draft GEAF submitted as Appendix to 2nd Technical Report. Accepted.
Communication strategy	The communication strategies was put in place in order to enhance extension of the project and its results to a wider audience.	Document submitted to IDRC and was used throughout the project implementation. Accepted
Development of baseline survey instrument,	The team produced the baseline survey instrument for producers, marketers and consumers.	Document was used for baseline study in August 2015.

Recruitment of project staff	All the project staff in Nigeria and Benin were recruited: • Project Assistants (10) • Regional officers and Technical Officer (20 staff) • Infographics and website expert (2) • Drivers (3) • Load Agents for scaling up (5) • Administrative staff (02) for Benin	Reported to IDRC.
Recruitment of graduate students	The project recruited a total of 17 PhD and 24 M.Sc and 20 BSc students in Nigeria and Benin: -05 PhD In Social Sciences , -10 PhD Biophysics , -02 PhD In food technology The project also recruited 24 Masters students -12 Social Science -8 Biophysics -04 Technology • Six (20) Bachelor students in all fields The UofM and UofS also recruited • One postdoctoral fellow, three MSc students and 2 three PhD students who managed all daily lab activities related to the research work on value addition, vegetables processing and synchrotron studies	Reports submitted to IDRC and accepted. The project extended the recruitment to 61 students in total (17 PhD, 24 M.Sc, and 20 B.Sc). Detailed list, subject and level of completion is available in a separated report of student training asAppendix 11in this Final Report.
Sites selection for project activities,	In Nigeria, the microdosing agronomic trials were conducted at six locations (Ogbomosho, Ilesha, Araromi, Akanran, Ile-Ife and Ilora) while in Benin one intensive researcher managed trial took place in the experimental field of the National Institute of Agricultural Research of Benin INRAB Ina –CRA- North –.	Field work completed and Comprehensive report was submitted to IDRC. Accepted.

Pre-project assessment/baseline survey	Baseline surveys conducted with 2678 respondents (1198 men and 1480 women) made up of 1357 producers, 583 marketers and 738 consumers. FGD was also conducted at 38 locations with 252 respondents. We used android software for data collection. This approach minimized errors in data collection and entry as well as helped in collecting Geographical Positioning System (GPS) information which will serve as part of the quality assurance and also provide spatial data for geo-referencing of findings.	Comprehensive baseline report and FGD analyses were submitted to IDRC. IDRC accepted the report.
Establishment of young vegetables scientists club (YVSC)	The project established the YVSC in a total of 181 secondary schools. We documented this achievement as part of our scaling up report. Overall over 80,000 students were part of the YVSCs.	Updated report is attached to this Final Report as a component of the Scaling up report (Appendix 5).
Purchase of Equipment	In Canada, Benin and Nigeria, we procured the following items of equipment: • Computer equipment (24 computers, 12 printers, 01 scanners, 08 cameras, 55 androids/tablets for field surveys) • Three vehicles (two Hilux and one Ford Ranger Pickup) • Lysimeters and soil hydraulic equipment • 15 motorcycles including 06 for technicians in charge of the implementation of the strategy for implementation with the communities and 02 student researchers in the field in both countries	All equipment were used for the project. Reported to IDRC and accepted.

	• Several laboratory equipment were purchased by the Canadian partner organizations.	
Comprehensive Report on field studies on fertilizer Microdosing:	Field studies were conducted at five locations in Nigeria while one intensive researcher managed trial was conducted at the experimental field of the National Institute of Agricultural Research of Benin INRAB Ina CRA North in Benin.	Report was submitted as Appendix to the 4th Interim Technical Report and accepted by IDRC. Updated Regional Report is attached to this Final Technical Report (Appendix 2).
Report of the International Scientific and Impact Advisory Board(ISIAB)	We held three ISIAB meetings and the suggestions of the Board assisted tremendously in the implementation of the project.	Reports of ISIAB meetings were submitted to IDRC. The reports were accepted.
Annual meetings and field visits to review the progress of our project (2015-2018).	The MicroVeg Project held a project review meeting yearly. We held meetings in Nigeria, Benin Republic and Canada at different times. Our meetings attracted several participants, including, IDRC, the Principal Investigators, NGOs, policy makers and officers of our institutions. We carried out a major field visit in Nigeria and Benin in 2016 while another major field visit was carried in Benin in 2017. The Regional Project Coordinator also carried out several field visits in Nigeria and Benin.	We submitted reports of our meetings and field visits to IDRC.
Specialized training of Nigerian and Benin staff through visits to the University of Manitoba and University of Saskatchewan.	Four Candidates were nominated and they were all trained at UofM and UofS. When we had issues with issuance of visa in Benin, the Global Affairs Canada resolved the matter and visas were issued to our students.	Training concluded.

Documentation of the impacts of crop diversification on resource use efficiency, resilience and gender equity	This portion of our milestone is very important for the assessment of the impact of our project and the effects on resilience and gender. We conducted an elaborate survey to obtain the necessary information.	The report is attached to this Final Report as Appendix 8.
Efficiency of the scaling up models(Innovations Platform and Satellite Dissemination Approach)	Our project used 2 scaling up approaches: Satellite Dissemination Approach (SDA) and the Innovation Platform (IP) Approach. We set up significant numbers of IP and SDA in Nigeria and Benin. We present a detailed and comprehensive report on the level of achievement of the two approaches and a comparison of the efficiency of the two scaling up models on Page 20 of Appendix 2. Both in Benin and Nigeria the innovation platforms performed better than the satellite dissemination approach in achieving scale up of technologies.	Report is Appendix 5 in this Final Report.
GIS-based information system and synchrontron analyses	As our online tools became more elaborate, we developed a parent website at www.microveg.ca to house our WebGIS information. We successfully produced a Web-based GIS system that allows one to visualize GIS data compiled from online sources as well as our project's research and also we developed a novel profit calculator. In addition we utilized high tech synchrontron innovation to study the soils of the project locations.	Our report is attached as Appendix 4 in this Final Report.
Training of farmers, 50% women on fertilizer micro-dosing and water management	The training of farmers was achieved. We developed a comprehensive report on **"Training of farmers on MicroVeg technologies: Fertilizer microdosing and water management"** across all the project target areas in Nigeria and Benin Republic. The major activities carried out in achieving this milestone were led by our NGOs.	A comprehensive report was submitted as Appendix to 4th Technical Report to IDRC. The updated report is submitted as Appendix 10 to this Final Report.

Value addition for indigenous vegetables through extraction, identification of compounds and formulation of functional (health-promoting) food products. Sensory evaluation of products and further training.	MicroVeg Project devoted significant resources into development of new vegetable-fortified flour-based products including bread, juices, cookies and chinchin/ petit-cailloux, and cereal and cowpea-based product- *Toubani and Alblo*. We also made significant progress in the extraction, identification of bioactive compounds, especially polyphenols, and biological activity evaluation of the products using advanced evaluation techniques *in vivo*. We developed innovative equipment for the fresh and dry conservation of the vegetables.	Comprehensive report submitted as Appendix 3 to this Final Report.
Training and demonstrations on value addition of indigenous vegetables	We launched rigorous training and demonstration programmes on value addition. Using good scientific practice/ethical procedures, we involved a wide array of human subjects in taste evaluation of our pastry products in Nigeria and Benin Republic while we conducted laboratory studies on laboratory animal models.	Comprehensive report is submitted as part of Appendix 3 to this Final Report.
Increased capacity for stakeholders (private partners, NGOs) on value addition of indigenous vegetables.	The innovations on value addition are targeted at private entrepreneurs including bakers, confectioners, pharmaceutical industries, policy makers and the consumers for expansion of business and for improvement of public nutrition. Production of "*indigenous vegetables fortified products*" represents a potential new economic income option for commercialization, and job creation either directly on the farm or in the local communities. We concentrated our efforts on increased capacity of stakeholders on value addition.	Comprehensive report was submitted as Appendix to the 4th Technical Report

MicroVeg meeting in Ottawa with IDRC, GAC and other stakeholders.	The MicroVeg Project represented by Clement Adebooye (Regional Project Coordinator), Rotimi Aluko (Principal Investigator, University of Manitoba) and Derek Peak (Principal Investigator, University of Saskatchewan) were invited by the IDRC and Global Affairs Canada (GAC) to present the results our project to the policy makers, scientific and business communities and private sector in Ottawa region. It was a full day meeting on Tuesday 16 May, 2017 in Ottawa. Our presentation at GAC was attended by 18 participants while 26 participants attended the presentation at IDRC. Derek gave a presentation on project overview, agronomic trial results and synchrotron tech plus GIS. Rotimi talked on value addition experiments and results while Clement gave information on the scaling up approaches. Overall, Marco, Frank, IDRC, GAC, academia and the private sectors were very happy to learn about the new things that our project is doing. Our presence will remain in their memories for quite some time. After the presentations we held a private meeting with Marco and Frank..	Just for mention and for records.

IDRC Photographer Visited Benin Republic: April 27 - 30, 2017	In an attempt to permanently document the achievements of MicroVeg Project, the IDRC commissioned a photographer, Mr Bartay Photos, San Francisco, USA to visit our project locations in Benin Republic from April 27-30, 2017. The aim is to capture both in picture and in video, all the action points of MicroVeg Project including agronomy, water use, irrigation, fertilizer microdose application, marketing, value addition, marketing and utilization of indigenous vegetables. The photo actions and videos are already on IDRC website.	Photos and video are available at https://www.flickr.com/gp/92096525@N04/V24Ds6
Gender mainstreaming and analyses report.	We carried out the gender mainstreaming and follow up analyses at twenty nine (29) communities with forty five (45) farmers groups in seven States of Southwest Nigeria.	Report is attached as Appendix 7 to this Final Report.
Intensification of awareness creation through radio and TV programmes	In Nigeria, we launched four daily radio programmes called *Ramo Elefo* (Ramo the Vegetable Seller) in local language which is aired on four (4) FM Radio Stations daily while in Benin we launched 15 radio programmes on Fraternité and Nato FM Radio, Canal 3Monde TV which have signals that reach the remote communities. We placed the project advert in the popular early morning programmes (8.00am-10.00am) that majority of the population listen to. An estimated 10.0 million people in southwest Nigeria listen to these programmes on daily basis while an estimated 8.0 million people listen to the awareness programmes in Benin and outside. Other awareness creation strategies are:	Report is submitted as Appendix 6 to this Final Report.

	• Project website (www.microveg.org). About 20,090 viewers have visited our website since March 2017 when started monitoring the web traffic. • Printed materials/marketing collateral (brochures, factsheets, posters, branding on sample products). We have given branded gifts and we also brand our value added products. • Events (fields days and market days, workshops and training programmes, media field trips, press release and web stories, continual engagement with media). Several events and training sessions have been held and reports on training are included in this Technical Report. • Scientific and conference publications, Newsletters and bulletins. We have presented several papers at conferences and published newsletters and bulletins. We have reported these to IDRC severally. • Social media (WhatsApp and Facebook). We had reported how we keep track of our farmers through WhatsApp and how we plan quick intervention with the help of this technology.	
Production of newsletters, extension leaflets, bulletins, media coverage on indigenous	Our project produced three fully detailed newsletters and four detailed bulletins on value addition (food fortification), one on microdosing TLVs and four training manuals. The newsletters and bulletins which were widely circulated among the stakeholders have also been shared with IDRC and also launched on our project website (www.microveg.org). Our project website	All these communication products are available at www.microveg.org . They were also submitted to IDRC and accepted.

vegetables value addition, fertilizer micro-dosing, water management, seed production and marketing	(www.microveg.org) and facebookgroup (https://www.facebook.com/groups/1153038891375500/ are also regularly updated and are active. Between March 2017 and now, we recorded a traffic of 20,516 visitors on our project website, and over 1000 members of the facebook group. We have also produced video recordings for food preparation and we are using the facility for training of our	
Status of training of MSc and PhD students	The status of studentship of each of the MSc and PhD students who are engaged by MicroVeg project is presented as Appendix 12. It is to be noted that we have graduated one (1) PhD, 15 BSc students and 8 MSc students. Additional 12 MSc and 3 PhD students will complete their programmes in 2018. A comprehensive summary of the status is attached.	Report is submitted as Appendix 11.
Published results and further publication plan	We are glad to report that in the last 36 months we have published 23 peer reviewed high impact journal articles, and 09 others are under-going review at the journal level. We presented over 30 papers at international conferences. Beside the 16 conferences papers already accepted for publication in *Acta Horticulturae*, a batch of more than 20 papers are in preparation for submission.	Report as Appendix 12.
Draft policy document to government in Nigeria and Benin	A draft policy document is already produced and we will explore the political climate to introduce this to the policy makers.	Draft policy attached as Appendix 13 to this Final Report.

4.0 SYNTHESIS OF RESEARCH ACTIVITIES AND RESULTS

To view a comprehensive pictorials of all the project activities that are discussed and described under this section, the reader can access https://www.flickr.com/gp/92096525@N04/V24Ds6 . The IDRC coordinated the photo-shoot (Bartay Photography, San Francisco, United States) which produced all photographs in the photo gallery.

4.1 **Comprehensive project impact assessment report :**

We contend that this project (IDRC 107983) has fulfilled the overall goals and achieved the majority of outcomes as conceived in the original proposal. Research/science, scaling up and extension, participating farmers and other stakeholders have demonstrated that IVs can be sustainably grown with microdosed fertilizer rate, harvested, processed/value added, marketed and consumed, thus reducing the risk of poverty and improving the nutritional quality and quantity of food stocks in southwest Nigeria and Benin. The following abstract provided by the Project Impact Task Team – Pages 5-6 (See full report in Appendix 1) summarizes the impact of our project:

"*The average number of years of formal education of the household head at baseline was 8 but at the endline the years of formal education increased significantly to about 10 years which is an indicator that more educated persons are entering the IV value chain. The typical vegetable farm size at the baseline was about 0.02ha while the farm size increased to 0.71ha at the endline representing an increase of over 350%. In terms of land acquisition, female who were generally not allowed to acquire farm land mainly due to tradition are now able to lease land for IV cultivation due to MICROVEG intervention. The econometric estimation of the impact shows that participants were able to increase their IV farm size by about 0.15 ha more than the non-participants. This is a significant increase in farm size and ultimately income obtainable from the enterprises. Due to the project intervention, people who were farther away from water source who would ordinarily not be interested in IV cultivation were able to increase their farm size by over 350% (0.02ha to 0.71ha) over the life of the project. Income obtained from the IV enterprises increased by over three times from about $700 to $2100 weekly at the peak (dry) season. Due to increased income obtained from the enterprises, the household dependency ratio reduced significantly from 3.52 (about 4 people at baseline) to 2.58 (about three people at endline)) as more people were able to take care of themselves at the endline. Amount of inorganic fertilizer used also decreased comparatively to baseline and there is an increase of cultivated areas and productivity. Microdose fertilizer application improved the benefit of IV production by 1.8 and 2.0 times, respectively when the fertilizer is used directly or diluted in water.*

For marketers, the average age which was 42 years at baseline dropped to 38 at the endline, indicating that younger people are entering the value chain with more than 97% female involved. An interesting observation is that younger women are entering the marketing component of the IV value chain. The project also succeeded in engaging better educated people in marketing as the average years of formal education increased from seven years at baseline to 11.36 at endline. More than 97% of marketers are female and the marketing households have an average of two dependants down from four at baseline. In terms of consumption, all the IV varieties are better consumed at the endline compared with only Ugu and Amaranth at baseline, suggesting that households in the study area

are better informed of the existence and benefits of IVs compared to other vegetables in the study area.

We note with interest our result that participants in the MicroVeg project were mostly educated married female farmers with small family size, who are close to water source and not given to religious taboos. However, for conventional vegetable producers the key features are that they are monogamously married and do hold some religious taboos. This result suggests that the MICROVEG intervention achieved the objective of gender-sensitivity in the study area. Hence it can be concluded that the project was gender and youth friendly."

4.2. Comprehensive report on fertilizer micro-dosing and water management studies for indigenous vegetables.

We successfully concluded the fertilizer microdosing and water management studies in Benin Republic and Nigeria. Field studies were conducted at five locations in Nigeria while one intensive researcher managed trial was conducted at the experimental field of the National Institute of Agricultural Research of Benin INRAB Ina CRA North in Benin. The comprehensive report is attached as Appendix 2. We present below the key messages from our findings:

- The average fresh leaf yields of the four vegetables increased from 1.3 and 3.2 kg/m² under control (no fertilizer) reaching a maximum of 2.55 and 6.5 kg/m² under 60 kg/ha of urea-N application in Benin and Nigeria, respectively. A contributory factor to this yield increase is the basal application of organic manure at a minimum rate of 5 t ha^{-1} to sustain the soil productivity.

- The total variable cost incurred on each $6m^2$ plot at 0 kg, 20 kg, 40 kg, 60 kg and 80 kg Urea-N/ha were $2.94, $3.32, $3.34, $3.37 and $3.42while the total incomes were $23.65, $40.51, $45.89, $61.08 and $39.52 , respectively**.**

- The combined application of fertilizer micro-dosing and manure (5t/ha) in continuous production during one year of Amaranth (4 cycles), Telfairia (one cycle), Solanum (2 cycles) and African Basil (2 cycles) led to a positive N balance under Amaranth (+60.8 kg/ha for D60) and African Basil (7.4 and 33.8 kg/ha for D40 and D60 respectively). K and P mining is corrected only when manure (5t.ha) is renewed at each crop cycle or higher amount is applied instead.

- Partial nutrient balance computation (nutrient input minus vegetable leaves nutrient uptake) showed that continuous vegetable (*Solanum, Telfairia, Amaranthus* and African basil) production without manure depleted the soil in N (-268.3 to -30.8 to kg/ha for D40, -195.0 to -4.5 kg/ha for D60), P(-65.0 to -18.3 for D40 and –286.0 to -18.7 kg/ha for D60) and K (-336.3 to -2.3 to kg/ha for D40, -2703.2 to -2.4 kg/ha for D60), although soil nutrient mining was moderate with African Basil.

- When fertilizer microdosing is combined with 5 tons of organic manure, our results showed that the residual macronutrients in the soils after three cycles of vegetable harvest was not significantly from the traditional fertilizer applications method. This shows that fertilizer micro-dosing can be used to sustainably produce these vegetables when combined with organic manure at the rate of 5 t per ha.

- The average water use by the vegetables in each crop cycle (dry season and rainy season) ranged from 285-377 mm in the forest and savanna agro-ecologies, respectively. Fresh biomass yield increased at an average rate of 31 kg ha^{-1} per 1 mm of water used in the rainforest, while in the dry savanna while it increased at an average rate of 27 kg ha^{-1}). The water required to produce a Kg of Amaranth was reduced from 450 L on the traditional irrigation method to 200 L under the capillary irrigation. This translated to water saving of approximately 2.2 million L/ha in forest to an approximate 8 million L/ha in the savanna ecosystem.

- Vegetable production based on 0.5 ha land area resulted in a net revenue of $3,879.00 and $3,650.00 in Benin and Nigeria, respectively. Benefit cost analysis revealed that in Benin, every $1 invested in vegetable production generates a return of about 0.8 cents and 0.5cents in Nigeria.

4.3 Value addition, food fortification, processing and preservation methods

Our studies on value addition, processing, preservation, polyphenol extraction and food fortification progressed impressively in Benin, Nigeria and Canada. Our report is attached as Appendix 3. Significant messages from our 36-month studies are listed below:

- We developed a low-cost (~$12/unit) sun-drier and charcoal-powered oven as a means of converting fresh leaves into dried leaves with storage or shelf-life of 12 months. Drying was completed within 4-5 hr and dried leaves reconstituted with water for use as regular soup ingredients showed acceptability that is consistent with that of fresh leaf soup. Seventeen (17) drying units were installed and used by farmers. These local technologies can be readily adopted in rural areas.

- We developed new technology on packaged boiled-frozen vegetable leaves that have been taken up by third parties who are now using the existing distribution channels for fish and meat marketers to provide access to refrigerated and frozen vegetables in Benin. We are glad to report that more than 600 distribution points were contracted by the project to market the frozen vegetable product.

- We developed a protocol for vegetable polyphenol extraction and we successfully utilized the polyphenol for fortification of local foods, juices and pastry products. The fortified foods were also evaluated for sensory properties and consumer acceptance. Indeed, the popularity and acceptance of the green bread have been greatly enhanced such that it now features prominently as part of the diet of many people within the

Obafemi Awolowo University campus, Ile-Ife, Osun State, Nigeria. Also, the overall acceptability of other fortified foods and beverages was very similar to those of the control products. The vegetable-fortified pineapple juice has been on sale in bottles and test-marketed in several local Cotonou and Parakou stores with great success, which supports consumer acceptance and a promising commercial impact.

- We demonstrated the ability of the polyphenol concentrates to reduce blood pressure and also inhibit digestive enzymes, such as α-amylase, α-glucosidase, and pancreatic lipase related to obesity and diabetes. Especially active were the polyphenol concentrates from *Telfaria occidentalis* and *Amaranthus viridis*, both of which reduced the blood pressure of spontaneously hypertensive rats (SHRs) by up to 40 mmHg. Test in human subjects will be next subject of research. This opens the possibility of developing a variety of nutraceutical products.

- Our research showed that using the standard conversion for rat to human dose, a typical 70 kg man or woman will require ~1 gram of the polyphenol concentrate from from *Telfaria occidentalis* and *Amaranthus viridis* per day for efficient blood pressure reduction. This polyphenol concentrate dose is equivalent to the consumption of 21 grams of fresh leaves on a daily basis, which can be readily achieved based on food consumption patterns in West Africa. However, the key message to the population is regular (daily) consumption of this amount of leaves in order to benefit from the blood pressure-lowering ability. If regular consumption is not feasible in some instances, then supplementation with the polyphenol concentrate either as a powdered drink (the product is highly soluble in water) or added to beverages. For some part of the population, intake of the concentrate in the form of nutraceutical capsules alone or in combination with vegetable leaf consumption may be the most feasible route to obtain antihypertensive benefit.

- Vegetable fortification also led to extended shelf life of some of the food products; for example, *Chin-chin* and green-bread stayed fresh 2-3 days longer than the regular white bread. The extended shelf life is attributable to the presence of antioxidant polyphenols, which would reduce the need for use of synthetic antioxidants in such wheat-based products.

- A critical part of our work showed strong inhibition of trypsin, which possess a catalytic activity that is similar to those of viruses. Therefore, the trypsin inhibition achieved in MicroVeg project could form the basis for the use of the leaf polyphenol concentrates as preventive agents against viral infections. But more importantly, our results suggest that increase consumption of these leafy vegetables may protect human beings against viral infections and diseases. This is a very important finding since infants and children are highly susceptible to viral diseases (especially diarrhea, flu, etc); regular use of these vegetables as normal dietary agents could limit this type of infections.

- A very important finding from our study was that the vegetable leaf-fortified bread was highly enriched (up to 200 times) compared to the well-known synthetic powerful antioxidant compounds. For example, our study showed that the catechin and quercetin contents of bread were increased 200 times as a result of vegetable leaf fortification. Rutin and myricetin, which have also been demonstrated to be highly bioactive were enriched up to 150-fold in the fortified bread. The results provide scientific evidence for the potentially powerful antioxidant quality of the fortified bread and could be used as part of the specifications to achieve intellectual property claims that support novelty of the baked product.

- The fortified foods were also evaluated for sensory properties and consumer acceptance. This aspect is very important since taste, flavour, colour and eating qualities determine the successful introduction of novel food products. The main noticeable effect of vegetable leaf incorporation was the increase in green colour. Indeed, the popularity and acceptance of the green bread have been greatly enhanced such that it now features prominently as part of the diet of many people within the Obafemi Awolowo University campus, Ile-Ife, Osun State, Nigeria. Availability of the green bread on the campus continues to be made possible through the Food Science and Technology Department bakery.

- In order to disseminate information on mode of preparation and production of the fortified foods, several training sessions were conducted that featured various stakeholders such as farmers, rural-dwelling population and bakers. Specifically, a total of 5466 persons (68% women) across 25 locations were trained on the promising value addition innovations. This is in addition to the training of 100 bakers. Training sessions included teaching of fundamental principles of the fortification processes followed by hands-on demonstrations. To ensure versatility and increased utility among the rural population, the instruction materials and product recipes have been translated into the Yoruba, the main language in Western Nigeria and also spoken in some parts of Benin Republic. Additional promotion was achieved through product demonstrations at various regional conferences or meetings. We also demonstrated profitability of the fortified bread and snack products, which indicates potential for establishing economically feasible production and marketing processes.

- Pre-commercialization marketing continues both in Nigeria and Benin. We continued to have scheduled meetings with the Standard Organization of Nigeria (SON) in order to obtain formal regulatory approval for the fortified food products. At the last meeting held in Lagos with the Director of Standards, discussions centred on the need to ensure that certain production protocols are free of food safety issues and specific chemical composition information required for certification and commercialization approval.

4.4 GIS and sychrontron studies:

As our online tools became more elaborate, we developed a parent website at www.microveg.ca to house our WebGIS information. We successfully produced a Web-based GIS system that allows one to visualize GIS data compiled from online sources as well as our project's research and also we developed a novel profit calculator. In addition we utilized high tech synchrontron innovation to study the soils of the project locations. Our report is attached as Appendix 4.

Highlights of our findings are:

- Our project has taken MicroVeg agronomic research results and linked it with climate and soil data using cutting-edge GIS tools.
- We have produced an online version of our GIS database to publish our project's results across the region. Additionally, we have produced some print-quality maps that are downloadable from our website that can be found at: https://groups.usask.ca/microveg/downloadable-maps.php
- We developed a profit calculator to estimate fertilizer and water needs for any site in Benin Republic and Nigeria using our project's results and a logic model we developed (http://webgis.usask.ca/microveg/ProfitCalculator.html). These data can be exported to a profit calculator that we coded to take all the MicroVeg data for a given spot, and calculate the profit associated with using the MicroVeg agronomic package. Currently, USD, CAD, Euro are enabled but we are working on a script to convert to NGN for Nigeria and CFA for Benin.
- We performed synchrotron-based research on sustainability of MicroVeg technology using the Canadian Light Source (CLS) and used the results to infer the sustainability of MicroVeg practices on soil health.
    - We found that the forms of carbon (C) depend upon ecoregion rather than the vegetable choice or fertilizer application, implying that this element is not strongly affected by MicroVeg over the time frame of this project.
    - We found that the forms of soil nitrogen (N) are strongly influenced by the MicroVeg inorganic fertilizer input. We observe decreased total N levels in MicroVeg plots compared to manure-only samples, but the organic forms of soil N had shifted from decomposed forms into more protein-rich forms. This suggests that MicroVeg additions are increasing plant biomass and yields, and inorganic N is cycling and will be available in the seedbed.
    - We found that Phosphorus (P) had some initial dependence on ecoregion, with soils from the Sudano-Savannah being higher in calcium phosphate before planting. However, the major changes in available P are due to a combination of N fertilizer addition and the choice of vegetable. These results suggest that later harvests of *Amaranthus* could benefit from a side-dress NPK application.
- From the totality of our soil nutrient and synchrotron analyses, we conclude that MicroVeg is a beneficial innovation for resource limited rural farmers to increase yields and fertilizer efficiency.

4.5 Efficiency of the scaling up approaches

Our project used 2 scaling up approaches: Satellite Dissemination Approach (SDA) and the Innovation Platform (IP) Approach. MicroVeg Project utilized two major scaling up models: the **Satellite Dissemination Approach (SDA)** and the **Innovation Platform (IP)**.The hypothesis behind the **Innovation Platform Approach** is that cooperation among stakeholders and actors enhance adoption and scaling up while **Satellite Dissemination Approach** relies on information and capacity building (training, demonstration, information) etc to reach the same goal.

We set up significant numbers of IP and SDA in Nigeria and Benin. We present a detailed and comprehensive report on the level of achievement of the two approaches and a comparison of the efficiency of the two scaling up models on Page 20 of Appendix 5. Both in Benin and Nigeria the innovation platforms performed better than the satellite dissemination approach in achieving scale up of technologies. Summary of our findings are presented below:

- The main stakeholders that play a role on the value chain of indigenous vegetables are: farmers, marketers, processors, input sellers, transporters, extension, policy makers and financial institutions.

- The scaling up objective of the MicroVeg project was achieved through the professional and technical support of the five NGOs (The Green Generation, The IAR&T, Alpha Omega Environnement AOE, Association pour la Recherche et la Promotion en Pisciculture Intégrée AR2PI and ZACOZA-ONG) that were recruited since the inception of the project. The NGOs played significant role in active development of the outreach, awareness creation, and organization of meetings, extension and negotiations. These key activities that were shouldered by the NGOs ensured the success of the scaling up of vegetable technologies to reach and exceed the targets.

- Our project reached a total of 337,931farmers (50.6% female) in 36 months. The total number of farmers (vegetable producers) reached in Nigeria is 229,750 (51.6% female) while in Benin, 108,181 farmers (46.3% female) were reached through both scaling up models, SDA and IP. This shows that the project has effectively reached target number of 255,000 farmers planned for the project period.

- We integrated 181 secondary schools 124 in Nigeria and 57 in Benin) into MicroVeg Project Young Vegetable Scientist Club (YVSC) and we trained them in vegetable science and production technologies. We also trained 957 teachers made up of 881 teachers (46% female) in Nigeria and 76 teachers (38% female) in Benin. We are glad to report that there was no YVSC in the schools at the take-off of our project but we established these clubs and we reached 82,713 students (51% female) in Nigeria and 30157students (41% female) in Benin.

- By this final reporting period, the project had reached 124 schools, trained 881 teachers (46% female) and 82,713 students (51% female) in Nigeria, while in Benin 57 schools had been reached and training of 76 teachers (38% female) and 30 157 students (41% female) on fertilizer microdosing and value addition.

- The total revenue generated by the YVSC in Benin and Nigeria were USD 2 197 and USD 2 428, respectively. The project distributed 6,625kg of *Ugu* seed (*Telfaria occidentalis*), 1085kg of *Igbagba* seed (*Solanum macrocarpon*), 2200 kg of *tete* seed (*Amaranthus*). We also donated 200 knapsack sprayers, 120 irrigation pumps, 120 irrigation hoses (50 m each), 10 fuel generators, 5 deep wells, 250 watering cans. Hoes and cutlasses, 75 MicroVeg planters, 500 bags of urea fertilizers and 1000 sachets of seed dressing treatment to farmers as incentive

- Male constitute a total of 952 (59%) of the total actors in the innovation platform and they dominate the transportation business (almost 100%) and 82% dominance of government agencies while the female gender is clearly dominant (81%) in vegetables marketing.

- At the IP level in the vegetable value chain, fewer male gender (25-30%) had problems with transportation, marketing, access to land, access to loan, control of pests and diseases and access to fertilizer and inputs compared to 70-75% in the female gender.

- In Benin and Nigeria, the Innovation Platforms reached more farmers than Satellite Dissemination Approach. The number of farmers reached by IP in Benin increased from 855 (12 months) to 9,353 (36 months) whereas SDA increased from 200 (12months) to 1,766 (36months) per district. In total for IP and SDA enabled to reach 10,005 farmers (12 months) to 108,181 farmers (36 months).In Nigeria, the number of farmers reached by IP increased from 33,600 (12 months) to 226,500 (36 months) whereas the SDA increased from 1498 (12months) to 65,615 (36months). SDA reached almost one fifth of the performance of the IP in Benin while in Nigeria, SDA reached more than one sixth of the performance of IP. The average women share was 51.3% for Nigeria and 46% for Benin.

- As at March 2018, a total number of 337,931farmers was reached by the two scaling up approaches in the two countries with 51.1% female.

- In Nigeria, as at March, 2018 majority of the actors at IPs were vegetables producers (229,750) (51.5% female) while in Benin, producers are 108,181 (46.3% female). Vegetable marketers (21,528) (71.2% female) in Nigeria while in Benin, vegetable marketers (6,948) (72.2% female). Vegetable processors were 561 in Nigeria and 12,562 Benin with 62.5% and 98% female, respectively while extension

service officials were 945 in Nigeria and 65 in Benin with 52.4% and 21.5% females respectively. Seed suppliers were 478 (48.1% female) in Benin while in Nigeria, seed suppliers were 140 (32.1% female). Least actor was recorded with the transporters with 1.3% female in Nigeria and 0% female in Benin.

- As a result of our scaling up activities, both at SDA and IP levels, within three years of MicroVeg project intervention, average land area under vegetable production in Benin increased from 985 ha to 2,575 ha in the period of 12 to 36 months representing 161% increase. Also, average land area under vegetable production in Nigeria increased from 9,105ha to 79,110 ha within the same period representing 768% increase.

- The average land area per farmer increased from 0.02ha to 0.07ha in Nigeria and from 0.03 to 0.06 ha in Benin, within the period of MicroVeg intervention. Women adopted more (three times) microdosing technology than men in all districts under IP.

- The average land devoted to microdosing on IVs in IP districts was three to four times that of SDA. The average land area under microdosing technology increased from 11ha/district (18 months) to 280ha/district (36months) in IP compared to 4 – 33.26 ha/district in SDA in Benin. In Nigeria however, average land under micro-dosing increased from 23ha/district to 120 ha/district under the IP compared to 9-30ha/district under SDA.

- Involvement of many actors along the vegetables value chain, through the Innovation Platform (IP) enables MicroVeg to understand issues of concerns in the entire value chain. The issues of concern include lack of facility for dry season farming, lack of high quality seeds, poor access to land, lack of organized transportation, pests and diseases problems, poor fertilizer supply. In response to those constraints, MicroVeg project provided the necessary intervention to address the concerns of the different actors. A comparative analysis (2015 vs 2018) of the level of concerns between male and female farmers showed that with MicroVeg's IP intervention, the gap between men and women farmers is closing up. This is because women now have equal access to and control over resources.

- In Nigeria, to ensure unhindered credit sourcing for vegetables value chain actors, our project initiated and signed MoU with LAPO Microfinance Bank (MfB). MicroVeg negotiated the interest rate on the loans and the repayment period with the LAPO MfB. Loans are to be repaid between 6-12months at an interest rates of 3.6% monthly (other bank loans in Nigeria attract at least 19% interest rate) with repayment to commence at the end of 60 days after release of funds and an incentive of a 40% draw back on interest for farmers who complete loan repayment by the end of the loan duration.

- Nigeria MicroVeg facilitated the negotiations with LAPO MfB with farmers in

attendance and today we are pleased to report that as at March, 2018, LAPO MfB has provided a total loan of NGN13 million (US$37,142=CAD47,514) for vegetable production to our farmers.

- After careful considerations of the IP and SDA success factors, IP was adjudged to be the most vibrant and useful tool to disseminate and scale up technologies among smallholder farmers.

4.6 Assessment of the series of dissemination/ activities

For MicroVeg Project, we used the under-listed communication strategies and tools. While, the Benin Team submitted a report on its effort and global assessment to reach the population using our communication tools, the Nigerian team evaluated the impact of the its most efficient tool, the daily radio jingle, "*Ramo Elefo*". The comprehensive report is attached as Appendix 6. Generally, highlights from the efficiency of our communication tools are:

- We have reported the wide coverage of our daily radio jingle/programmes, reaching a total population of about 10,000,000 people daily. The programme has a household name in Nigeria, "*Ramo Elefo*". Our occasional TV programmes in Nigeria and Benin Republic are also reaching sizable number of people.

- Project website (www.microveg.org). A total of 20,516 viewers have visited our website since March 2017 when started monitoring the web traffic.

- Printed materials/marketing collateral (brochures, factsheets, posters, branding on sample products). See http://microveg.org/images/news-and-reports/MicroVeg2017/MicroVeg-Bulettin-Value%20Addition-FINAL-NEW-web.pdf and http://microveg.org/images/news-and-reports/MicroVeg2017/MicroVeg%20Newsletter-February%202017-FINAL.pdf and http://microveg.org/images/news-and-reports/MicroVeg2017/2017-January/MicroVeg_Newsletter-2017-January.pdf . We have given branded gifts to participants at our Training Programmes and we also brand our value added products e.g. syrup, pasty products, green bread, etc.

- Events (fields days and market days, workshops and training programmes, media field trips, press release and web stories, continual engagement with media). Several events and training sessions were organized and reported to IDRC in our previous reports. A quick reference on some of the important events is presented below:

Event	Date	Location
Awareness creation on the food value of indigenous	June 2015 to	Organized locations in Benin and Nigeria (at project target zones)

vegetables	September 2017 (usually weekly	
Press conferences	Several between March 2015-2018	Held in Nigeria and Benin. We addressed the press and featured in TV programmes. Most of these coincided with our several project meetings.
Market day meetings	June 2015-March 2018	Several of such meetings in Benin and Nigeria.
Conferences, Workshops in Nigeria, Benin and Canada	March 2015-March 2018	Scaling up workshops and AfriVeg Conference in Cotonou. We made presentations at several levels in Canada. Many conference appearances in Nigeria
Meeting with GAC, IDRC and Canada public	May 2017	Ottawa, Canada
Field days	Sept 2015-March 2018	Several field days in Benin Republic and Nigeria at target locations.
Media field trip	July 2016 and April 2017	Bartay Photographer commissioned by IDRC and our own media field coverage
Web stories	March 2015-2018	www.microveg.org https://www.facebook.com/groups/1153038891375500/
Training programmes on fertilizer microdosing, value addition and general IV value chain	June 2015-March 2018	Several training sessions in Nigeria and Benin Republic.
International meetings (Saskatoon, Manitoba, Cotonou, Nigeria)	March 2016, March 2017, Feb 2018.	Some of the meetings included the MicroVeg team, university top officers, policy and extension.

Highlights of our Communication and Dissemination Activities:

The project intensively used three major mass media: radio, TV, newspapers/magazines. The media strategy reached up to 8 million people in Benin Republic and more than 10 million in Nigeria. We targeted international audience media (Canal Monde TV in Benin and Channel and NTA in Nigeria) and also local FM radios (Orisun FM, Oluyole FM, Adaba FM, Kwara FM, 104.5 FM and BCOS in Nigeria and Fraternite FM, ORTB in Benin) broadcasting in local languages. MicroVeg team participated in the Cooperation and Professional Insertion day of the University of Parakou in Nov 2015 and 2016 to inform the public on importance, opportunities of IVs. Nigeria team participated and promoted IVs value chain in the Prison (training inmates) and trained Osun State Youth Empowerment Scheme (OYES) members in 2015, 2016 and 2017. The teams also participated in other fora and workshop for promoting IVs at national and regional levels. Some highlights are:

- The *"Ramo Elefo"* radio programme was categorized as "very helpful" by most (63.5%) of the 880 respondents meaning that the radio program is helpful to the respondents in their vegetable production activities. Further, 62.33% of the respondents who saw the programme as relevant are females.

- In terms of age groups, those aged between 25 and 50 years categorized the program as being most relevant, on the other hand, those aged below 15 years categorized the radio programme as being least relevant. Thus ***suggesting that the radio programme is not as relevant to children as it is to those within the active productive age.***

- Most (52.11%) of the respondents are satisfied with the contents of the radio programme, while only about 1.58% of the respondents are not satisfied.

- As regards awareness by the respondents, respondents were more aware of bed preparation as an innovation with 36.3% of respondents being aware of it. About 12.5% of the respondents are aware of the MicroVeg innovation on value addition.

- As a result of the awareness creation, an increase in cultivation from 1.33% to 39.4% for "igbagba", 12.22% to 45.7% for "ugu" and 3.33% to 39.4% for "tete atetedaye" were recorded. These increases were obviously due to the awareness created by the radio programmes in addition to the demonstration efforts of the extension services and scaling up.

4.7 Gender mainstreaming and analyses report.

We carried out the gender mainstreaming and follow up analyses at twenty nine (29) communities with forty five (45) farmers groups in seven States of Southwest Nigeria. Group discussions were held with the farmers during training sessions while individual interactions took place on the farmers' plots. The farmers were disaggregated into younger (247) and older

farmers (452). The younger farmers were between the age of 18 and 35 years while the older farmers were between the age of 36 and above years. We also took care of the singles, married, widowed and divorcee, and other vulnerable groups such as prisoners and unemployed youths. Key highlights of our findings are presented below (Appendix 7):

- About 32% of the vegetable farmers attained tertiary education while about 1 out of every five of them had no formal education (21%), another 24% and 23.8% had primary and secondary education, respectively. Further investigation however revealed that those with tertiary education had formally retired from civil service and were only engaged in vegetable farming as post retirement income generating activity.

- There were differential access to hired labourers by men and women. More women than men use hired labourers and more men than women clear the land by themselves. This was explained in terms of the care (e.g. feeding and being more considerate) that women farmers gave to labourers than their male counterparts. Farmers also reported that women vegetable farmers made use of hired labourers than male vegetable farmers. The cost of labourers varied from between ₦30,000 ($100) to ₦100,000 ($300) per acre, depending on the location.

- For transplanting, both men and women reported that the planter supplied by MICROVEG was gender friendly as it was easy to use for both men and women including pregnant women and nursing mothers.

- The vulnerability of the farmers also affects their access to important inputs such as land, fertilizers and labour for vegetable production. For example, it was found that vulnerable groups such as female widowed and divorcees had smaller farms than their female counterparts due to limited access to fund to lease land.

- Interestingly, in Lagos State, farmers in Badagry reported that they mostly got the land from the Government at ₦1 million (US$3000) for 8 hectares of land for one year. But farmers in Alimosho also within Lagos State, also reported that they got their land from a private individual and the price range from ₦3000 ($10) to ₦12000 ($40) per plot (100 m x 50 m) for one year. Access to land could be through lease, purchase or inheritance at several other locations but culture forbids women from claiming title to land in parts of Kwara State.

- Gender roles have negative influence on irrigation and water management technology. For Instance, women often stop vegetable production during dry season in Ogun State due to lack of water so as to have enough time to get water to irrigate their husband's farms.

4.8 Documentation of the impacts of crop diversification on resource use efficiency, resilience and gender equity.

This portion of our milestone is very important for the assessment of the impact of our project and the effects on resilience and gender. The report is attached as Appendix 8. We combined the data sets for Benin and Nigeria, and ran detailed statistical analyses. Our results are summarized in 10 bullets points below:

- Female vegetable farmers are older than their male counterparts with an average age of 45.6 years and 50.3 years for Benin and Nigeria, respectively. The majority of male and female vegetable farmers are middle-aged with an age range of 31-55 years.

- The level of formal education (88.8%) among female vegetable farmers is higher than the level of formal education (80.5%) among male vegetable farmers in Nigeria. In contrast, the level of formal education (40.0%) among male vegetable farmers is higher than the level of formal education (14.0%) among female vegetable farmers in Benin.

- For land acquisition, some male (32.1%) and few female (16.2%) farmers lease their farm land in Nigeria while very few male (3.10%) and female (0.62%) farmers in Benin lease their farm land. Few male (19.9 and 24.8%) and female (12.4 and 11.2%) farmers in Nigeria and Benin, respectively, inherited their farm land.

- In terms of use of fertilizer, vegetable farmers in Benin applied fertilizer at the rate of 129.7 kg/ha which is above the recommended rate of 112.5kg/ha, while vegetable farmers in Nigeria applied 26kg/ha which is below the recommended rate of 80kg/ha.

- With respect to seed sourcing, results showed that seeds saved from last season production provided about 51% of the planting material while seeds purchased from the market provided 12-32% of the planting material. An exceptionally high percentage (75%) of the vegetable producers in Benin purchased their seeds from the market.

- Vegetable production based on 0.5ha land area resulted in a net benefit of $3,879.00 and $3,650.00 in Benin and Nigeria, respectively. Benefit cost analysis revealed that in Benin, every $1 invested in vegetable production generates a return of about 0.8 cents and 0.5cents in Nigeria.

- In Benin, the total output and total variable cost were 19,800kg and $6,934.01, respectively while in Nigeria, they were 4,481.55kg and $2742.96, respectively. Gross profits were $1,544.48 and $4,900.23 in Benin and Nigeria, respectively. For every kilogram of vegetable marketed, a profit of $0.08 and $0.11 would be expected in Benin and Nigeria, respectively.

- Vegetable farmers who diversify, use the productive resources available to them more efficiently. Results showed that farmers who diversify use mostly wetland for their operations, especially during the dry season for maximum productivity and profit. In terms of fertilizer use, those who plant two UIVs use the most volume (665.27kg of NPK and 441kg of Urea on 0.5ha of farmland) whereas those who planted all four vegetables used the least amount of fertilizer (less than 50%). In the two countries, cultivation of three types of vegetables yielded highest income for the farmers

- Majority of vegetable farmers with small farm holdings in Benin Republic (100%) and Nigeria (67.1%) experience shortage of food for between zero and three months every year.

- Different forms of business models exist in the UIV value chain. This varies from the use of "cartel" in marketing to "contract" farming in production. The particular model engaged in depends on the location and the business environment.

4.9 Economic empowerment and marketing of the indigenous vegetables:

This economic empowerment and marketing study provided the basic economic features for the indigenous vegetables which were not previously available in the study area. The study determined the characteristic features of marketing channels, and determined the factors promoting the consumption of the selected UIVs. The report is attached as Appendix 9. Highlights are summarized below:

- Indigenous vegetables (IVs) marketing in both Nigeria and Benin Republic is predominantly female dominated with over 90% female participation in both countries. Whereas marketers in Nigeria are relatively older and have up to 12 years formal education their Benin counterparts are younger with fewer years of formal education.

- IV marketers in both countries do prefer to market a variety of vegetables species involving both indigenous and conventional vegetables.

- In marketing the IVs, the main value addition techniques utilized in Nigeria is blanching (50.8%), re-bunching (47.1%) as well as packaging and sorting (30.9%), whereas in Benin Republic there is in addition to these techniques the extraction of juice/syrup by 16.3%.

- The revenue obtainable from the marketing of IVs in Nigeria increased by about 119.7% over the project period (36 months) and that of Benin Republic also increased by 90.1%. This shows clearly economic advantage by the participants who are mainly female and confirms the empowerment motive of the intervention.

- The economic returns obtainable from UIV marketing in both countries shows a highly profitable venture. In Nigeria, the cost-benefit analysis ranged from 1.42% to 2.35%. With a market interest rate of about 20% in Nigeria, the enterprises are profitable. In Benin Republic the cost-benefit analysis ranged from 1.22-1.32% which is also a very profitable range.

- The marketers adopted new business models to boost their marketing and value addition activities in both countries. In Benin Republic the marketers were linked with micro-small enterprises to boost the sales of the improved IVs products, however, in Nigeria, the IVs marketers teamed up to take advantage of the existing business models to expand the volume of their sales. The export model received a boost from the MICROVEG intervention in Nigeria.

- In Benin, an innovative Sale Counter Kit has been developed and distributed (30) to IVs marketer to enhance the presentation, the access, the preservation and to promote IVs in several markets. The Kit enabled to increase the turnover of IVs marketers.

4.10 General report on training of the population across the MicroVeg sectors:

Our team made significant effort to pursue the dissemination of our technologies to the population, focusing on the women, youth and the vulnerable groups. The comprehensive report is attached as Appendix 10. Highlights of our major achievements are presented below:

- In Nigeria, , in the area of seed production, handling, storage, processing and packaging, 544 farmers (49% female) were trained while in Benin 72 farmers (38% female) were trained.

- Vegetable value addition technologies were scaled up to processors with a total 836 actors (70% female) trained in Nigeria while 630 processors (83% female) were trained in Benin.

- Private Organizations and government representatives (305 in Nigeria and 310 in Benin) have been engaged during all training sessions during this reporting period. .

- Our project engaged in the training of vulnerable groups especially prison inmates. We trained 600 prison inmates (10% female) at the Nigerian Prison Service, Ilesha, Osun State Nigeria on vegetable production technologies. We provided irrigation facility for the Prisons to ease dry season production.

- In August 2017, an AWARD of appreciation was presented to Prof Clement Adebooye - the MicroVeg Regional Project Coordinator by the Controller of Prison (CP), Osun State in recognition of MicroVeg's developmental work especially in the area of

provision of irrigation facility (borehole), supply of seeds and capacity building in vegetables production.

- Further engagement with the Osun State Youth Empowerment Scheme (OYES) programme with the establishment of 15 ha capacity commercial *Ugu* farm in Ilesha and support from Osun State Government. OYES vegetable production activities has raised almost a million Naira ($2,498) as at September, 2017. This is already influencing policy in Osun State.

- As a result of the promising results, the Governor of Osun State paid a visit to the central vegetable farm and further committed more support in funding and land allocation to the OYES program while pledging to support MicroVeg in the adoption of vegetable policies in Osun State.

- In Benin, we organized an award ceremony for entrepreneurs with innovative ideas on traditional leafy vegetables to encourage the former graduates of the University of Parakou to undertake business on leafy vegetable production. In Nigeria, Young Vegetable Scientists club (YVSC) school quiz competitions were organized in 2 States: Osun and Ondo states, Nigeria. Prizes were awarded at the competitions.

- A total of 1,221,000-CFA and N382, 800 (>$1000) was generated by YVSC in Benin and Nigeria, respectively and this is currently supporting school projects and rehabilitation.

ADDITIONAL REPORTS:

Status of students and publications

- The status of studentship of each of the MSc and PhD students who are engaged by MicroVeg project is presented as Appendix 11. It is to be noted that we have graduated one PhD, 08 MSc students and 15 BSc students. Several (16) MSc and 16 PhD students will complete their programmes in 2018.
- A detailed plan for publications, indicating status of manuscripts intended journals and timelines. Full report is attached as Appendix 12. We are glad to report that in the last 36 months we have published 23 peer reviewed high impact journal articles and 09 others are under- going review at the journal level. We have not less than 30 papers presented at conferences while 16 conferences papers are already accepted for publication. A batch of more than 20 papers are in preparation for submission

AfriVeg Forum 2017 https://afri-vegforum.org/

- Since sustained production and utilization of indigenous vegetables (IVs) will be a solution to the persistent problems of food and nutritional security in Africa, our project therefore considered it timely to organize a forum to discuss issues that are

related to the production and utilization of the indigenous vegetables of Africa from the perspectives of science, technology, finance and policy. Therefore, we floated an international conference in Cotonou Benin Republic in November 2017. One of the goals of this conference was to bring together the stakeholders in the indigenous vegetables value chain. The conference focussed on development of improved agronomic methods, improved value addition, post- harvest and processing technologies, financing and the development of new market outlets which would contribute to the economic well-being of the rural women and generally enhance the average family income and provide a bulwark against food and nutritional insecurity. A total of 11 countries, 79 researchers, IDRC and GAC attended the conference.

- The best presented papers are now ready publication in a special issue of *Acta Horticulturae* devoted to "traditional leafy vegetables: from plot to plate". The *Acta Horticulturae* is published by the International Society for Horticultural Science (ISHS) with headquarters in Belgium.

5.0. SYNTHESIS OF RESULTS TOWARDS AFS OUTCOMES:

This project was planned to generate 4 tangible outcomes as goals: 1) develop and fine-tune fertilizer microdosing agronomic practices and value addition technologies for indigenous vegetables, 2) expand the scope and reach of the innovation to more farmers through the use of two scaling up models, 3) increase yields and income through value addition, preserve soil and enable fertilizer cost saving, and 4) promote policy advocacy for the integration of the successful scaling up model into local, national and regional food security programs in West Africa. At the end of 36 months, our project provides tangible support to the following AFS outcomes:

5.1 Increasing agricultural productivity (Availability):

Fertilizer microdosing and water management: Our work on fertilizer microdosing has shown that we can optimize productivity on-farm through efficient and effective management of use of fertilizer. We have reported significant increases in yields of vegetables through precise use of low rate of fertilizer. This has both economic and environmental benefits. We also developed a manual fertilizer applicator and transplanter which are gender-friendly, lightweight, and affordable. As a result of our scaling up activities, within three years (36 months) of MicroVeg project intervention, average land area under vegetable production in Benin increased from 985 ha at baseline to 2,575 ha at 36 months representing 161% increase. Also, average land area under vegetable production in Nigeria increased from 9,105 ha to 79,110 ha within the same period representing 768% increase. The average land area per farmer increased from 0.02 ha to 0.07 ha in Nigeria and from 0.03 to 0.06 ha in Benin, within the period of Microveg intervention. Women adopted more (three times) microdosing technology than men in all districts under IP.

In the area of risk mitigation we have done the following:

- Insect pest control: Beetles bore holes on vegetables leaves of *Tete* and *Ugu* at some sites in Nigeria. We utilized the botanical insecticide of liquid extracts from neem

leaves as foliar spray. Maximum protection occurred after two sprays.

- Drying and packaging indigenous vegetables – Locally manufactured vegetable charcoal/solar dryers to preserve excess vegetables produced during the rainy season have been constructed and tested. Drying excess fresh UIVs retains the quality and greatly prolongs shelf-life of the product, thus extending the supply of a variety of nutritious food products well beyond the normal wet season.

- Capillary irrigation system for TLVs nursery and production plots: We developed, successfully tested and disseminated an innovative capillary irrigation system for traditional leafy vegetable nursery. The system enable to save up 1.2 – 7.4 million L of water per ha in a growing season and highly enhance seed germination and early growing (See App 2).

5.2 Improving access to resources, and/or markets and income (Accessibility):

Our project engaged land owners at IP levels in Kwara State Nigeria because women were restricted from access to land and land resources for agriculture. MicroVeg project negotiated with the traditional land owners at the IP level and we are glad that about 350 women can now farm on irrigated land in Kwara State. In Nigeria, to ensure unhindered credit sourcing for vegetables value chain actors, our project initiated and signed MoU with LAPO Microfinance Bank (MfB). MicroVeg negotiated the interest rate on the loans and the repayment period with the LAPO MfB. Loans are to be repaid between 6-12months at an interest rates of 3.6% monthly (other bank loans in Nigeria attract at least 19% interest rate) with repayment to commence at the end of 60 days after release of funds and an incentive of a 40% draw back on interest for farmers who complete loan repayment by the end of the loan duration. Nigeria MicroVeg facilitated the negotiations with LAPO MfB with farmers in attendance and today we are pleased to report that LAPO MfB has provided a total loan of NGN13 million (US$36,470=CAD46,856) for vegetable production to our farmers.

In the area of youth engagement in Nigeria, a major boost for our project during this reporting period is the partnership with Osun Government Youth Empowerment Scheme (OYES) a youth development program organised by Osun State government, southwest Nigeria to enhance entrepreneurship. MicroVeg has engaged and trained the 10,000 OYES members who are also called "Farmers Brigade". We connected the OYES farmers to our project through WhatsApp platform. The address of our WhatsApp platform is MICROVEG O'VEG. The farmers report the progress on the farms and activities through this platform. Our technical team attends immediately to the reports of the OYES members through prompt visits. The Nigerian OYES vegetables farmers are practising vegetable production for the first time. This is a major boost for MicroVeg project. MicroVeg supported OYES with inputs (irrigation facilities, seeds, knapsack sprayers, watering cans, cutlasses, hoes and fertilizers) to start up their own farms. The OYES is already reporting significant profit of 100-300% from sales of vegetables. For youth engagement in Benin Republic, a competition of young entrepreneurs in indigenous vegetables was

launched in early November 2016 in collaboration with the Entrepreneurship Development Center (CDE) of the University of Parakou. The initiative was to support projects regarding new and innovative models of production of leaves and / or seeds, marketing LFTs and innovative added value addition enterprises. A least two hundreds applications were received and 20 were selected and trained on the 23rd February 2017 on leafy vegetable production science (microdosing, water management, value addition) and on agricultural entrepreneurship and business. The second round was launched on 2nd March 2017 for the final selection of candidates was concluded and training accomplished. In the area of partnership in Nigeria, engagement of value chain stakeholders has proven to be beneficial. Our project established MoU with the British American Tobacco Nigerian Foundation (BATNF). As a result of collaboration with BATNF, about 4500 farmers have been integrated into our project and we are jointly supporting the farmers with training and inputs in the seven States. BATNF relies on our project for technical and practical skills on vegetable production. As a result of the collaboration, we MicroVeg is regularly invited to project review meetings of BATNF. In the area of partnership in Benin Republic, the project in collaboration with the ZACOZA PRODUCTION social entreprise developed an innovative distribution and sales counter kit of added value indigenous vegetables. Production from Innovation Platforms are collected and processed (washing, boiled and frozen indigenous vegetables. The added value indigenous vegetables are then packed distributed with market shops (those equipped with freezer or cold chamber and are used to sell frozen fish). The indigenous vegetables Sales Kit of ZACOZA-Production Social Entreprise highly increased the number of farmers engaged in indigenous vegetables production and reach of consumers in Cotonou and Abomey-Calavi, the two most densely populated cities in Benin. 30 TLV Sale Counter Kit (Kit Comptoire de Vente) were distributed to different farmers groups.

5.3 Improving nutrition (Utilization)

In addition to improving and increasing the quantity of indigenous vegetables food production, we have successfully produced and evaluated:

- New innovative recipes for vegetable-fortified bread, cookies, chinchin, *toubani*, maize custard (*ablo*) and syrup. The products have been generally well accepted by taste panels.

- We have also made significant progress in the extraction, identification of bioactive compounds, especially polyphenols, and evaluation of the products using advanced evaluation techniques.

- Production of vegetables-fortified pastry products represents a potential new economic income option for commercialization, and job creation either directly on the farm or in the local communities. It can also open new business options for chemical and pharmaceutical industries that are interested in polyphenols.

- We developed prototype innovative post-harvest tools and technologies to preserve the nutrient quality and prolong the shelf life of these indigenous vegetables. As an example, we designed and fabricated a charcoal/solar powered portable dryer that has the capacity to dry 50 kg of fresh vegetables in an hour. Taste test panels consisting of both women and men farmers and some family members, confirmed that consumers would eat re-constituted sun-dried chopped green vegetables as part of their traditional daily dishes.

- We developed an evaporative cooling system for preserving indigenous vegetables in wholesome state for at least 7 days.

- The advantages of these technologies are reduction of postharvest losses, readily available high quality dry vegetables, low operational cost, operation easy to use and maintain, gender friendly, locally sourced raw materials for fabrication.

5.4 Engagement of Canadian researchers with southern research organizations

Canadian researchers and expertise are intimately linked with their discipline counterparts in Nigeria and Benin Republic. This project has boosted Anglophone-Francophone understanding as well as establishing what is expected to be a long-term partnership in West Africa (Nigeria and Benin). The project has advanced beyond professional network and it has produced close friends and confidants. Collaboration with Canadian expertise in agronomy, food science, soil science, GIS models, environmental sampling and monitoring has been very instrumental in the implementation of all aspects of MicroVeg project. Derek Peak (Soil Science UofS) has contributed significantly to synchrotron analyses, GIS model and environmental sampling and management of our soil samples. The analyses are still ongoing and comprehensive report is submitted in this final report. Rotimi Aluko (Nutritional Sciences UofM) made significant contribution in the advanced laboratory investigations on polyphenols, in vivo evaluation of the polyphenols and scientific evidence for nutritional and health benefits of polyphenol-enrich pastry products. Two PhD students from Nigeria and Benin Republic did their research in Rotimi Aluko's Lab (UofM) while two other PhD candidates joined Derek Peak's lab at UofS. Total chemical composition and potential effects of fertilizer dosage and time of application on mineral composition are provided in this final report. Benefits to Canadian Institutions included improved international recognition, exchange opportunities, as well as graduate student recruitment and training.

During the development of project proposal, the principal investigators adopted a TASK TEAM approach to organizing and coordinating the various science disciplines required to implement the project. Each TASK TEAM consisted of members from each of the 5 collaborating partner Universities. The various teams have struggled at times to coordinate activities and reports, but "team work" takes work, patience and persistence to function fully. The project has adopted the slogan TEAM WORK MAKES THE DREAM WORK as a mantra to encourage closer cooperation and coordination. A major intention and perhaps the ultimate objective of our team is to maintain our team spirit, partnership,

collaboration and cohesion. We have evolved in an Anglophone-Francophone synergy to create a team with excellent communication system, mutual understanding and respect. We will continue to develop joint proposals for funding and look for opportunity for exchange and consultation. We will also be willing with IDRC and GAC again when the opportunity avails. We will also use our team as a model to build other bilingual teams between Africa and Canada.

5.5 Informing policy

Our project has been a clear demand for the research results from the policymakers. MicroVeg has been able to provide convincing degree of expertise in vegetable production and value addition technologies and this has enabled the policy makers to have confidence in our expertise. There is incontrovertible evidence that the policymakers are *using* the results from our project.

Our success stories are highlighted below:

- The engagement of our project engaged in the training of vulnerable groups especially prison inmates is a major boost for our influence on policy. We trained 600 prison inmates (10% female) at the Nigerian Prison Service, Ilesha, Osun State Nigeria on vegetable production technologies. We provided irrigation facility for the Prisons to ease dry season production. For this effort, in August 2017, an AWARD of appreciation was presented to Prof Clement Adebooye - the MicroVeg Regional Project Coordinator by the Controller of Prison (CP), Osun State in recognition of MicroVeg's developmental work especially in the area of provision of irrigation facility (borehole), supply of seeds and capacity building of prisoners in vegetables production. We are glad to report the prisoners are now producing their own vegetables, selling to Prison Officers and realizing money for themselves, even while in jail.

- Our project has established direct links with the Standards Organisation of Nigeria (SON) and process has begun to establish the NIGERIAN STANDARD for green pastry products which had not existed before now. SON has also commenced the process of formulating policy to hasten certification of such manufactured products in Nigeria. In Benin Republic, the project has established a partnership with the Direction de l'Alimentation et de la Nutrition Appliquée (DANA) to commence the process of certification of the value added products.

- The Obafemi Awolowo University, Ile-Ife has approved the marketing and sales of green bread on the campus. Marketing of bread fortified with 3% vegetable was introduced to the Obafemi Awolowo University community in February 2017. Consumers welcomed the bread and sale has improved tremendously. In Benin, marketing posts have been established at University of Parakou (UP) and University of Abomey-Calavi (UAC), as a key activity of university YSVCs and sales of fresh, value added vegetable take place every Tuesday and Friday on campus.

- Partnership with the Osun Government State Youth Empowerment Scheme (OYES) where we engaged the 10,000 members as vegetables producers.

- Partnership with the Kwara State Government (Kwara Go-Veg Initiative) to build the capacity of youths and women in vegetable production and also Christdiamond consultancy agency in training of farmers on Telfaria cultivation.

- Other partnerships were also established with Nigeria Bank of Agriculture, Nigeria Regulatory Agency for Drugs and Food (NAFDAC), Royal Exchange Microfinance, Industrial and General Insurance Company and Nigeria Export Promotion Commission

6. Challenges encountered/ Actions taken

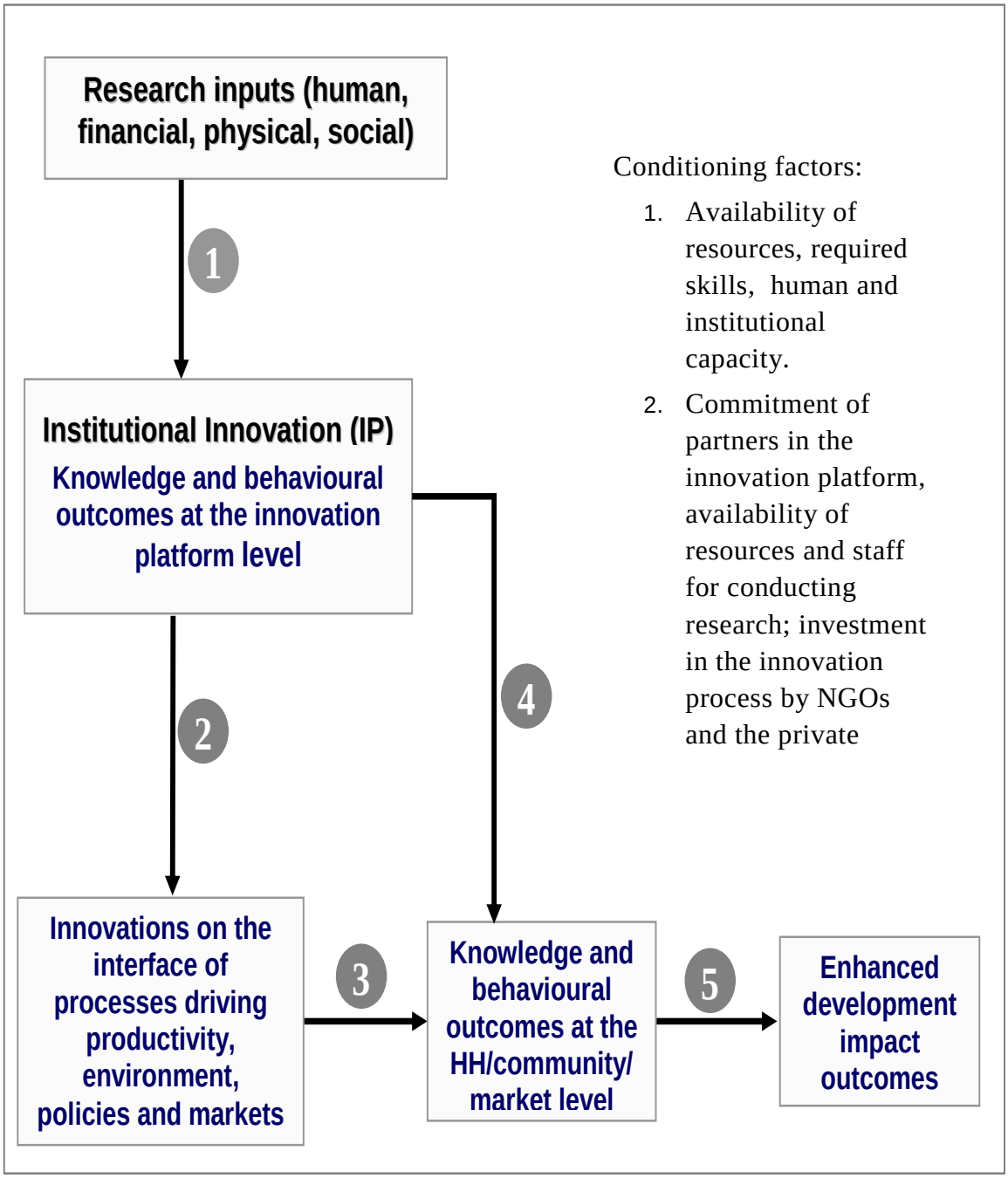
The major challenge is with the late response of task teams to request for team's report which has contributed to the delay in submitting this Final Technical Report.

Other minor challenges are:

- Coordination between multiple institutes which pose important challenges for projects in common.
- Differences in administrative structures and requirements for managing funds also result in problems for coordinating research activities in the field.

7.0 CONCLUSION

To finally conclude, we present a schematic summary our IV innovation scaling up model showing the integration and linkages of the various components investigated in this project. We contend that this scaling up model has good potential for application at a much broader scale to alleviate poverty and increase food security in West Africa.


Research inputs (human, financial, physical, social)
1
Institutional Innovation (IP)
Knowledge and behavioural outcomes at the innovation platform level
2
4
Innovations on the interface of processes driving productivity, environment, policies and markets
3
Knowledge and behavioural outcomes at the HH/community/ market level
5
Enhanced development impact outcomes
Conditioning factors:
1. Availability of resources, required skills, human and institutional capacity.
2. Commitment of partners in the innovation platform, availability of resources and staff for conducting research; investment in the innovation process by NGOs and the private

8. RECOMMENDATION:

The five principal partners in this project appreciate the timely assistance of IDRC at all times. We have witnessed the positive impact of a Regional Project Coordinator in building a team approach in our project and helping with overall coordination and timely delivery of our report. We also recommend that any potential follow-up projects should include training and team-building exercises for collaborating scientist from various institutions to facilitate implementation, monitoring and evaluation; establishment and clarification of a project governance; and clearly defining the institutional roles, flexibilities and responsibilities.

We recommend that IDRC should establish the policy of having Regional Project Coordinators appointed for its funded projects, preferably from within the core writers of the proposal. The Regional Project Coordinator should be a versatile person with good knowledge and understanding of the proposal to be implemented. The role of a Regional Project Coordinator cannot be under-estimated in a multi-disciplinary research of this nature. The Regional Project Coordinator must have vast experience in managing projects and writing reports for IDRC. The International Scientific and Impact Advisory Board (ISIAB) also played a key role towards the success of this project and should be considered and continued for IDRC-funded project management mechanisms.

As a team, we recommend that IDRC should continue to support additional research on IVs and other "minor" or under researched crops in addition to the main staple crops. We discovered through our project that many people living in the urban centres were persuaded through the awareness campaign of MicroVeg and they are now regular consumers of IVs. They testify to the food value and palatability of the IVs. We are also glad that our project succeeded in proving that the IVs could be such economically beneficial for the livelihood of the resource-limited rural population who are now taking advantage to better their livelihood. Our value addition studies pointed to the direction of using the consumption of these IVs to solve some health issues. Therefore, our team is unequivocally encouraging IDRC to continue to promote the IVs and other minor crops across the world.

MicroVeg team seeks for a new grant from IDRC and GAC to continue our work on IVs because we have not yet reached a comfortable level of assured sustainability. We have identified three major areas of our project that need to be pushed forward with more research: a) Seed production to ensure sustainability and continuity of production of high quality IVs. We need to complete the development of a complete seed production system that could stand the test of time in order to ensure long-term sustainability. The seed production technology was not completed by MicroVeg because MicroVeg lasted only 3 years. Therefore, MicroVeg team will like to fine-tune the seed production technology to certification and train the seed producers. Granting us additional funding will guarantee the completion of this crucial aspect of our IVs project. 2) Value addition technology of MicroVeg has been very successful. However, we need to do some more intensive scientific work on polyphenols and human trial using IV-fortified food products. Since we are working on 'food for man' we must explore all

aspects of quality and safety through proper research. We are likely to secure a patent on this subject if we act fast enough. This will be a major achievement for both our team and IDRC-GAC. 3) Our GIS and synchrotron report presents short-term analyses results, tracking vegetable production and water quality over a longer-time frame would allow more confidence in the sustainability of the practice with respect to soil health. Also our web-based GIS is a product that, while polished, requires management and curation to persist past the CIFSRF project. It would be ideal to incorporate the WebGIS results into a freely available smart phone app that could empower farmers and NGOs with information such as market prices, extension agents, and other helpful information.