Darwin Initiative Main Project Annual Report

Important note: *To be completed with reference to the Reporting Guidance Notes for Project Leaders: it is expected that this report will be no more than 10 pages in length, excluding annexes*

Submission Deadline: 30 April

Darwin Project Information

Project Reference	22-012
Project Title	Harnessing agricultural ecosystem biodiversity for bean production and food security.
Host Country/ies	UK, Tanzanian and Malawi
Contract Holder Institution	Royal Botanic Gardens, Kew
Partner institutions	**Nelson Mandela African Institute for Science and Technology** **Natural Resources Institute, University of Greenwich (NRI)** **Lilongwe University of Agriculture and Natural Resources**
Darwin Grant Value	£ 288,762
Funder (DFID/Defra)	DFID
Start/end dates of project	01/04/2015 – 31/03/18
Reporting period	April 2015-March 2016 Annual report 1
Project Leader name	Philip C Stevenson
Project website/blog/Twitter	@chickpeaman
Report author(s) and date	Philip C Stevenson 30/04/16

1. Project Rationale

Tanzania's national poverty reduction strategy paper highlighted that food poverty exceeds 18% and agriculture is central to reducing this to 11%[1]. The step-change production increases required to achieve poverty reduction are realistic since yields of key crops such as beans (providing protein, micronutrients and vitamins in Tanzania and Malawi) are presently so low (500-700 kg/ha). Consequently, millions of farmers, particularly women (the primary bean growers in Malawi and Tanzania[2]) and their households, are at risk of nutritional deficiency and food insecurity[3]. Potential yields are >3000 kg/ha. Insects and the plant diseases they vector are the major biological constraint for beans[4]. Pesticides can control insects but are rarely used for reasons of economics and availability[5]. Biodiversity underpins agricultural ecosystem services and ultimately food security, livelihoods and economic development by augmenting natural enemies and reducing pest impacts[6], while bean yields are 40% lower without pollination[7]. Biodiversity in smallholder ecosystems, however, is poor in Tanzania and Malawi. Proposed biodiversity evaluations will identify plant species that support key beneficial invertebrates and enhance ecosystem

1 http://www.imf.org/external/pubs/ft/scr/2011/cr1117.pdf

2 http://www.researchintouse.com/nrk/RIUinfo/PF/CPP28.htm#L3

3 Abate et al., 2012. . *Tropical Grain Legumes in Africa and South Asia: Knowledge and Opportunities.* PO Box 39063, Nairobi, Kenya: International Crops Research Institute for the Semi- Arid Tropics. 112 pp.

4 Belmain et al. 2013. Managing legume pests in sub-Saharan Africa: Challenges and prospects for improving food security and nutrition through agroecological intensification. Chatham Maritime (United Kingdom): Natural Resources Institute, University of Greenwich. 34p

5 Stevenson et al., 2014. Pesticidal Plants for stored product pest in small holder farming in Africa. In "Advances in Plant Biopesticides" Ed. D. Singh. Springer Verlag. pp 159

6 Gurr et al. 2004 Ecological Engineering for Pest Management, CSIRO, Australia,

7 Bartomeus et al., 2014 Contribution of insect pollinators to crop yield and quality varies with agricultural intensification. *PeerJ* 2:e328

service and resilience and enable farmers to grow beneficial plants within their cropping systems to improve food security and alleviate poverty.

Project Map. Location of project in Tanzania (circled) is around Moshi & Himo and southern slopes of Kilimanjaro.

2. Project Partnerships

We have already been working with all partners on this project on other actions led by the UK partner Natural Resources Institute under McKnight Foundation and European Union funding, so already have a strong and effective working relationship. However, this is the first time Kew has led the an action with these partners and the first time as a partnership we have tackled large scale ecosystem surveys and this was originally challenging to set up. However, owing to our track record and good working relationship together we have managed to make progress in several areas. We have also engaged for the first time the services of a consultant who has designed and helped undertake and analyse the outcomes of the baseline survey and this has gone well. We expected input at the workshop from Malawi partners at LUANAR but the original lead has moved on and was not able to attend. However, we are currently developing the agreement for the Malawi partner to come on board officially. We are fortunate that our new local partner leader in Malawi has undertaken a landscape wide survey of invertebrates about which we report below to compliment the survey undertake in Tanzania.

3. Project Progress

3.1 Progress in carrying out project activities

A project planning workshop was held in Arusha 22-25 September 2015 and hosted by the Tanzanian partner and attended by Dr Iain Darbyshire (RBGK), Dr Sarah Arnold (NRI), Prof Patrick Ndakidemi (NM-AIST), Dr Kelvin Mtei (NM-AIST), Ms Julie Tumbo (Consultant Socio-economist) and Tanzanian students to plan activities including the baseline survey and implementation of field sampling. The workshop was used as a training exercise for prospective PhD student who were also appointed through this process. Both students took up their positions on January 1st 2016. Two outcomes from the workshop included a sampling survey methodology and a baseline survey tool (Minutes of this meeting can be found in Annex 4). **Principal Hypotheses were defined.**

1. Margin and arable weed plant diversity varies between fields and different ecological zones
2. Fields with higher plant biodiversity have higher insect biodiversity than those with lower plant diversity a) Higher pollinator abundance and diversity leads to more pollination services and higher fruit-set in crop b) Higher natural enemy abundance and diversity results in lower pest damage
3. Pollinator networks are more complex where plant diversity is high
4. Plant biodiversity and insect biodiversity change over the growing season. High plant biodiversity in flower before/after the main bean flowering season, supports higher pollinator diversity throughout the season and benefits pollination of beans

Sites (24) have been identified, in 3 ecological zones: low (c. 800m), mid (950-1100m) and high altitudes (1500-1600m) with 8 sites (fields) per zone. All the sites grow at least some beans, either as the main crop or intercropped with other crops (e.g. maize). It has been difficult to find identical representative locations for sampling at each altitude and even within each altitude. Sites also vary in size with some are large fields (100m along the edge) whereas most are smaller (<50m along the edge). Sites are divided into "intensive survey" and "minor survey" sites – ONE site per zone is allocated to intensive survey (this should be a large field), and the other seven are minor sites. Each site has been used to collect data about plant and insect diversity.
The surveys on **intensive** sites were based around a 50m margin transect and a 50m into field transect running perpendicular to the field margin transect. These sites will be surveyed up to 6 times over the season and these

times to coincide with pre-ploughing/cleaning, immediately after planting seeds, seedling stage, bean flowering, bean podding and finally, post-harvest.

Output 1: Preliminary plant surveys were undertaken at 4 locations that represented 3 altitudinal zones as described. Plant diversity observed and insects' visits to plants recorded. Abundant plant species at lower altitudes included *Euphorbia heterophylla*, *Justicia bracteata*, *Achyranthes aspera*, *Commelinna benghalensis*, and *Senna spectabilis*. Some including *Ageratum conyzoides*, *Bidens pillosa* and *Galinsoga parviflora* are noteworthy as being exotic (S. American) weeds, abundant in several locations, supporting large numbers of bees, Syrphidae (hoverflies), and butterflies and in the case of *Bidens* and *Ageratum* have known pesticidal properties. The natural enemies of bean pests, tachinid flies, long-legged flies, robber flies and assassin bugs were restricted to just one indigenous species *Phaulopsis imbricata*. Invertebrate surveys showed that the insect assemblage changed across the growing season and from one location to the next.

A second plant survey was undertaken from Feb 2016 as part of the training of the 2 new PhD students in field techniques (see annex for reports). This was initiated to record main plant species by cover and abundance in the test area and any changes in field margin and in field species over the cropping season. Two transects of 10 plots (1m X 1m) at locations alonghte field margin and in the fields that coincided with insect monitoring points, was undertaken as the principal species survey and at 7 other locations at this altitude (1000 masl). Surveys at higher altitudes will be undertaken in April 2016 to coincide with the plantings which occur later in the season.

Key species identified include *Richardia scabra*, *Commelina bengalensis, Conyza bonariensis, Bidens pilosa, Argeratum conyzoides, Euphorbia hirta, Desmodium* spp., *Conyza bonariensis, Euphorbia hirta, Senna spectabilis, Hyptis suaveleonsis*. Information about ground cover, relative dominance compared to other species, phenology (flowering?), transect orientation and a description of the plants were recorded. Voucher specimens were collected and deposited into the National Herbarium in Arusha with a second specimen of each species collected for sending to the RBG Kew herbarium - these will be used to verify the names of the important species identified in the field surveys. Climatic conditions over the course of the sampling period are also being monitored.

Further sampling will be undertaken during the growing season which bridges the reporting period (Late Feb to June/July). These later surveys will indicate the change in plant assemblage within fields which will obviously become primarily the beans crop – although this may be supplemented by the most persistent weeds. The field margin survey will provide an indication of the change in the plant assemblage and flowering species over the course of the crop development at the 8 locations at each of 3 altitudes.

Output 2*: Key invertebrate pollinators of beans and their key habitat (plants/ecosystems) established at 25 locations in 4 agro-ecological zones.*

The initial invertebrate surveys (pollinators, natural enemies and pests) was undertaken across 4 farm locations and at 3 altitudes (Annex 5). Invertebrate biodiversity in field margins and within fields was estimated. The number of functional invertebrate groups at different elevations and different times within the crop were relatively stable across the 3 zones but reduced as the season progressed whereas in field margins the functional diversity was lower at higher altitudes. Dolichopodidae and Tachinidae were most common taxonomic beneficial insect groups recorded: 685 and 313 individuals respectively. Dolichopodidae, assassin bugs, spiders, lacewings, ants and bees differed in abundance according to elevation. All taxa except spiders and ants changed in abundance over the course of the season (For details of data and results see annex 5).

A GLM revealed that abundances of all major taxa were influenced by rainfall, with rainfall generally corresponding to an increase in insects caught. Temperature had a more complicated relationship, but in general high temperatures (>30°C) were associated with severely reduced counts of many key taxa (Fig. 2). Tachinidae, assassin bugs and wasps were particularly differentially caught in the field margins rather than the crop itself ($p = 0.024$, 0.004 and 0.002 respectively) but other taxa were caught broadly equally in both the margin and the cropping area. Rainfall, temperature and elevation all influenced PC1, with rainfall increasing the population of beneficial insects but the numbers tend to decrease with increasing elevation. Ageratum conyzoides, Conyza bonariensis, Stachytarpheta cayennensis, Bidens pilosa and Galinsoga parviflora were observed to be visited by pollinators (bees, syrphid flies and butterflies) and therefore merit further investigation for year-round nectar provision, ability to support pollinators outside the bean flowering season, and pesticidal properties.

The second survey tool was developed at the workshop in Sept 2015 (Annex 4). Surveys of invertebrates were undertaken using pan traps and transect walks and this work is still underway (Annexes 6 and 7). Pan traps were placed every 10m along each transect containing water and detergent and left 24 hours after which insects were collected from each pan recording (Site, Date, Transect, Trap number, Colour). Insects were preserved in 70% ethanol or better. This allows insects to be identified to species level if possible, and genus or family if not with unusual specimens dried, pinned and kept to help established the insect collection proposed in the project. Each site is monitored 6 times per season, for 2 days each time (2 x 24 hour samples). Pollinator and natural enemy transects were undertaken along a transect that runs along the field margin, recording every sighting of an insect interacting with a flower within 1m of the observer and recording the species of the insect (if unsure, catch a specimen for later ID) and the species of the plant. At the minor sampling site one pan trap was in margin and one in crop on each minor site with each monitored 3 times per season. Also a pollinator and a natural enemy transect walk were made on each site 3x per season. These later insect surveys were only started in March so have not provided any concrete data yet although initial indications are that the earlier survey provided an accurate assessment of the key natural enemies and pollinators.

a) b)

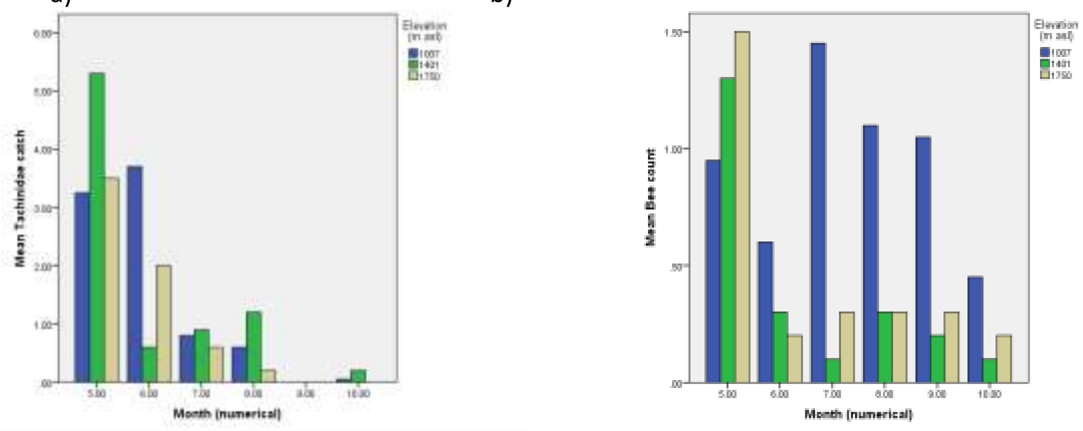

Fig. 1 Change in (a) Tachinidae (natural enemy) and (b) bees over the cropping season.

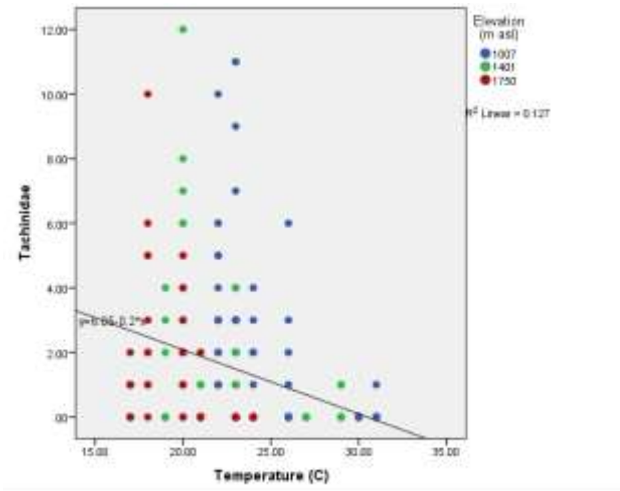

Fig. 2 Relationship between temperature and Tachinidae numbers caught

Output 3: *Capacity of 400 lead farmers increased by information and guidance on exploiting and maintaining agricultural biodiversity for improved crop yield.*

A farmer survey tool was developed in consultation with a socio economist employed independently and was implemented in March (Annex 10). The survey has collected information from 100 farmers so far but will reach the 200 proposed in May because at higher altitudes bean farming was not underway by the end of year one. The principal objective was to obtain evidence and information on how improved pest control and management practices in bean farming can lead to increased quality and yield and subsequently improved livelihood, living standards and welfare for bean farmers in Moshi district. The tool will be implemented in the early part of year two in the second partner country Malawi. A full report is provided a long with the survey tool in Annexe 3. As part of this survey the project will also investigate meaningful use of telephones to help provide and receive information from our target farmers. Baseline survey undertaken in Moshi – currently 100 farmers interviewed using a questionnaire indicated in annex 4 and data being analysed. Initial findings of survey suggest much room for improvement. Farmers are using various synthetic pesticides but their uses have some limitations. E.g., they can't be used during flowering stage because its poison can last for a long time even after harvest that makes bean seeds poisonous to consumers (but this will also kill pollinators). Farmers report that the short rain season (July-October) is not suitable for maize as they use irrigation system and the water is not enough for both maize and beans. Synthetic pesticides are understood by farmers to cause health problems as they are toxic and according to farmers, it causes flu and breathing problems when sprayed as the farmers don not wear protective gear. Some farmers are using both plant (especially leaves of neem trees) and organic (especially ashes and cattle's urine) pesticides. However, they said that it is time consuming to prepare especially plants and not as effective in eradication of insect pests so they also need to spray some synthetic pesticides to protect their crops from pests. **Most of the farmers are not aware about natural enemies.** Some farmers don't know even the common pollinators such as bees. From the pictures shown, they identified the natural enemies as insect pests. Most of the farmers identified ladybird beetle shown in the picture as the pest Ootheca.

Most farmers have seen the insect pests in their farms but they don't know their names. Most farmers don't know the importance of field margins in terms of harbouring beneficial insects. They think field margins harbour only insect pests and that's why most of them clear field margins and leave only trees, and even spray weed killer or burn field margin plants. Farmers practice either mono cropping or mixed cropping mainly due to season or insufficient land. Some farmers use synthetic pesticides though do not know their names because when they go to the agro-vet shops, they just explain what is happening with their crops and then the seller will advise on the 'appropriate' chemical to be used. Sometime farmers can collect a representatives of insect pests which attack their beans and show to agro-vet specialists so that they can get appropriate pesticides. Some bean varieties such as Soya njano has been mentioned by most of the farmers as one of bean varieties harbouring more insect pests though it is grown by most of them just because of its good price in the market. Most farmers claimed the need of agricultural education so as to apply best agricultural practices that will help to increase bean production.

Output 4: *Field margin plant species that support beneficial insects evaluated for their biological activity against pest insect species of beans and negative effects on natural enemies and pollinators determined.* This work will not be undertaken until year 2 and 3 because we do not yet know which are the potentially interesting species, although some preliminary work was carried out on cowpea to test some of the preliminary identified species such as *Bidens pilosa* in field trials in Malawi.

Output 5: *Post-graduates trained in conducting biodiversity surveys and carrying out field and laboratory based research.* The first pilot survey for invertebrates and plants was undertaken as described alongside training of 3 NMAIST MSc students under the supervision of Kew and NRI specialists and local partners. The work will be the main research activity written up for one MSc student's degree thesis (and has provided pilot data for development of future surveys. We proposed to recruit 1 PhD student in the original proposal. However, after approval of our application to McKnight Foundation in round 1 we increased the request to cover the costs of 2 X PhD students to compensate for a possible shortfall in MSc Students which may results from a change in government policy towards funding MSc research. This request was accepted but not until late August 2015, thus the recruitment of the PhD students was delayed longer than hoped and delayed progress we had hoped to make in the year 1. This issue was raised with LTS as soon as possible and we have agreed to move some of the budget from year 1 into years 2 and 3. The two students will focus on two different aspects of the research activities and we propose one to focus on the wider landscape plant assemblage and how this supports pollinators while the second will likely focus on immediate field margin species with a stronger focus on natural enemies and in particular parasitic wasps. Post-graduates were appointed through selective interview at NM-AIST and took up their roles officially in January 2016.Clearly this has held up some of the progress towards training and sampling. However the two new students are on track and already conducting surveys in the field of plants, invertebrates and helping with the baseline survey mentioned above. Part of this training program in year 1 comprised in field training in planting survey and invertebrate survey techniques.

3.2 Progress towards project outputs

Output 1:	*Ecosystems and plant species that are habitats for key natural enemies of bean pests identified*.			Comments (if necessary)
	Baseline	Change recorded by 2016	Source of evidence	
Indicator 1.1 Plant biodiversity surveys across 25 locations in TZ by year 2	No info available about plant species important to bean farming	Up to 20 species identified as common to bean fields in region	Section 3.1 of report provides some detail See Annexe.	Surveys completed by end of year 2.
Indicator 1.2 Insect biodiversity surveys across 25 locations in TZ by year 2	No info available about insect species important to bean farming	Key beneficial insects identified and associations with climate and altitude recorded	Section 3.1 of report provides some detail but see also **annexe 4.**	Surveys completed by end of Y2.
Indicators 1.3 Associations between habitat type and plant of invertebrate species diversity established	No info available about relationship between plant and beneficial insect species important to beans	Some associations between plants and insects determined in year one – need following up	Section 3.1 provides detail but data to be collected in Y2	Key associations identified by end of Y2.

Indicators 1.4 Plant species of importance to beneficial insects and with pesticidal properties identified	No info about insect species known to NM-AIST and farmers prior to project	Some plant species identified in surveys as abundant and providing important forage for beneficial insects include known pesticidal plants	Section 3.1 of report provides some detail	
Output 2:	*Key invertebrate pollinators of beans and their key habitat at 25 locations in 4 agro-ecological zones.*			Comments (if necessary)
2.1 **Five** important natural enemies of bean pests and their key plant species habitats identified and target pest species determined	No info about key plant species for beneficial insects known to NM-AIST and farmers at project outset.	10 natural enemy species identified as common to bean fields in region	Section 3.1 of report provides some detail. Review paper published on survey of beneficial insects in beans. **Annex 3.**	Surveys to be completed by end of year 2.
2.2 5 key/abundant pollinators of beans and most important non-crop species habitats identified by start of year 3.	No info about insect species known to NM-AIST and farmers prior to project	Key beneficial insects identified and associations with climate and altitude recorded	Section 3.1 of report provides some detail	Surveys completed by end of year 2.
5 most important pests identified and most important non crop habitats ID'd via abundance, perceived impact and literature.	Information about pests of beans known from earlier work but nothing about which non-crop plants are forage/refugee	Identity of 5 pests species that might be influenced by enhanced numbers of beneficial insects established. *Ootheca* sp. (two species), Aphids, Blister beetles, Leaf miners,	Section 3.1 of report provides some detail	Surveys completed by end of year 2
Output 3:	*Capacity of 400 farmers increased by information and guidance on exploiting and maintaining agricultural biodiversity for improved crop yield.*			Comments (if necessary)
Indicator 3.1	No info about farmer knowledge of beneficial insects or how this might affect productivity.	Survey undertaken through interviews of 200 farmers and still collating data and analysing.	Findings summarised in 3.1 and details provided in annexes	Surveys completed by end of year 2.
Indicators 3.2-3.5	No info about how new knowledge could inform farmer practise	No work undertake towards these indicators.		
Output 4:	Field margin plant species that support beneficial insects evaluated for biological activity against pest insect species of beans and negative effects on natural enemies and pollinators determined.			Comments (if necessary)
Indicators 4.1 Five plant species of potential importance as habitat and refuge for beneficial insects and with potential pesticidal properties identified.	Some field testing of plants indicates measurable effect but none from plant surveys	Five species tested on cowpeas in Malawi indicate some pest management benefits. One species *Bidens pilosa* is common in field margins and visited by pollinators.	Section 3.1 of report provides some detail	Surveys completed by end of year 2. Field trials currently assessing efficacy
Indicators 4.2-4.5	No info about plant species with pesticidal properties in Tanzania. .	No work undertake towards this indicators.		Some species common to Malawi &Tanzania, and worthy of further investigation.
Output 5:	Field margin plant species that support beneficial insects evaluated for their biological activity against pest insect species of beans			Comments (if necessary)
Indicator 5.1 At least 10 post graduate students trained and provided field experience in	None trained.	3 trained in field survey techniques – 2 X PhD student and 3 X M.Sc. students.	PhD first 3 months in Annex 4.	Training ongoing.

botanical surveys				
Indicator 5.1 At least 10 post graduate students trained and provided field experience in invertebrate surveys	None trained	3 trained in field survey techniques – 2 X PhD student and 3 X M.Sc. students.	Ndakidemi, B., et al., (2016). Am. J. Plant Sci., 7(03), 425.	

3.3 Progress towards the project Outcome

Outcome:	Smallholder farmers implement science-based methods for enhancing and restoring ecosystem services and biodiversity in agricultural systems that improve bean yield and quality, food security and rural livelihoods.			Comments (if necessary)
	Baseline	Change by 2016	Source of evidence	
Roles and interactions of key plant and beneficial invertebrate species of agricultural ecosystems understood by farmers and agricultural technicians by end of project.	Almost nothing is known about the importance of beneficial insects in bean farming in Africa.	Baseline survey asked questions about importance of insects to bean production so raising awareness about work however farmer's intervention later in the project will be required to demonstrate impact.	Annex 8, 10 and section 3.1	
Management methodologies that maintain ecosystem services and augment natural pest enemies and pollinators developed and implemented to increase yields by 20% from baseline data at project outset without additional agricultural inputs.	Little known about the impact on yield of enhanced ecosystem services.	Currently still acquiring information about the ecosystem biodiversity – too early to say exactly what yield increases might be achieved.	See Section 3.1 and Annexe 4-9	
Bean crop productivity and quality improved and monetary value of beans increased for 400 farmers by 20% by project end	Little known about the impact on yield of enhanced ecosystem services.	Currently still acquiring information about the ecosystem biodiversity – too early to say what increases achievable.	See Section 3.1 and Annexes	
Role of agricultural biodiversity in crop quality, enhanced yield and consequent poverty alleviating benefits demonstrated to key stakeholders through participatory field trials.	Currently acquiring info about ecosystem biodiversity so not yet know which species will be important I enhancing ecosystem services	Too early to say which species will be used to impact farming and yields.		
Yield and poverty impacts of enhanced biodiversity demonstrated through individual farmer surveys for bean production at project outset and project end that indicate increased income of 5-10% per household	No indication that yield is enhanced by exploiting ecosystem services in bean production in East Africa.	Baseline survey to assess levels of knowledge about ecosystem services and wealth have been carried out and info about	See Section 3.1 and Annexes	

3.4 Monitoring of assumptions

An analysis of the assumptions has been undertaken as part of the monitoring and evaluation and those highlighted at the project outset remain valid. Farmers will adopt interventions that enhance the delivery of ecosystems service provided they are engaged in an appropriate way and can be convinced of the benefits. At this early stage it's difficult to determine the level of engagements although we have 200 participants in the baseline survey in Tanzania. The project will to provide as much information as possible in local languages where necessary to ensure farmers are fully informed of the interventions proposed and the benefits

3.5 Impact: achievement of positive impact on biodiversity and poverty alleviation

Ecosystem services, including biological pest control and crop pollination, benefit food production[8]. Biologically diverse agricultural ecosystems are healthier and resilient and more likely enhance crop production through service provision and so underpin food security in smallholder farming. However, basic information on levels of diversity necessary to support beneficial invertebrates, and which are key plant species habitats for key pollinators and natural enemies is not known. The level of pollinator contribution to yield and quality and impact of natural enemies is absent for almost all crops in Africa including beans. Recent evidence from Europe indicates pollinators play a major role in yield (40% increase) and quality in beans[9] which are otherwise largely assumed to be self-pollinated, while ecological engineering of field margins augments natural enemies and improves food production in rice cropping systems in Asia[10]. While many field margin plants are crucial in providing habitat, refuge and forage for invertebrates beneficial to crop production – e.g. nectar and pollen for parasitic wasps and bees, especially outside cropping seasons, and habitat for spiders and carnivorous beetles -many of these plant species such as *Ageratrum conyzoides* also have pesticidal properties that can be exploited for pest management[11]. Currently the project is undertaking research towards obtaining the information required to progress farming towards a more ecologically aware approach that will deliver better yields. However the evidence for this will not be produced until later in the project.

4. Contribution to SDGs

This project addresses in part 6 SDGs
End poverty in all its forms. By enhancing crops yields.
End hunger, achieve food security and improve nutrition and promote sustainable agriculture. By promoting sustainable agriculture via alternatives to pesticides, enhancing ecosystems services of farmlands and ensuring better understanding of ecosystem sustainability in farming among beans farmers.
Ensure healthy lives. By providing alternatives to pesticides reducing exposure of users and consumers.
Achieve gender equality. Supporting bean production which is typically managed by women.
Ensure sustainable consumption and production patterns in particular to Support developing countries to strengthen scientific and technological capacity for more sustainable patterns of consumption and production.
Protect and restore and promote sustainable use of terrestrial ecosystems By providing farmers with knowledge and methods to manage farms in a way to support increased biodiversity.

5. Project support to the Conventions, Treaties or Agreements)

Project partner countries Tanzania and Malawi have ratified the CBD. This project supports CBD article 1 - conservation of biological diversity, sustainable use of its components and sharing of benefits arising out of use and article 6 - developing national conservation strategies and sustainable use of biological diversity into relevant programmes and policies. The project also contributes to bean production which is an ITPGRFA Annex 1 crop (*Phaseolus* beans). Agricultural ecosystem services will be improved through augmentation of pollinators and natural enemies of pests in bean production also addressing several Aihchi-2020 targets. Owing to the relevance of the project outputs to CBD we have established contact with CBD national focal points through NMAIST and LUANAR in Malawi and Tanzania. The current CBD national focal point in Tanzania is Mrs. Esther Shushu Makwaia, Principal Environmental Officer, Division of Environment and in Malawi is Dr. Aloysius Kamperewera Director, Environmental Affairs Department who have both been informed about this project and been invited to join an external advisory panel to evaluate relevance and progress of the action. We are also in communication with the Malawian ITPGRFA national focal point Lawrent L.M. Pungulani who is very supportive of the action (see accompanying correspondence). We have also notified Dr Fidelis Myaka, the National Focal Point in Tanzania for the ITPGRFA who also provided written support for the work.

6. Project support to poverty alleviation

Tanzania's national poverty reduction strategy paper highlights that food poverty exceeds 18% and agriculture is central to reducing this to 11% by 2015[12]. Insects and the plant diseases they vector are the major biological constraint for beans[13]. Beans are Tanzania and Malawi's primary legumes are produced on 1,500,000 ha and consumed by >20 million people in Tanzania and Malawi. Yields are chronically low (<500kg/ha in Malawi) but are potentially ~3T/ha. Yet beans are a critical protein and mineral source for poor rural households and income to

---

8 Bommarco et al., 2013, *Trends in Ecology and Evolution*. 28, 230-238
9 Bartomeus et al., 2014 *PeerJ* 2:e328
10 Zhu et al., 2014, *PLoS One:* 9: e108669
11 Stevenson et al., 2014. Pesticidal Plants for stored product pest in small holder farming in Africa. In "Advances in Plant Biopesticides" Ed. D. Singh. Springer Verlag. pp 159 & Amoabeng et al., 2014 PLoS One. 8(10): e78651
12 http://www.imf.org/external/pubs/ft/scr/2011/cr1117.pdf
13 Belmain et al. 2013. Managing legume pests in sub-Saharan Africa: Challenges and prospects for improving food security and nutrition through agroecological intensification. Chatham Maritime (United Kingdom): Natural Resources Institute, University of Greenwich. 34p

farmers, particularly women - the major growers of this crop. About 35% of the production in Malawi, for example, is marketed, contributing about 25% of total household income for over 68% of the households who sell surplus[14]. An increase in yield and quality of 20% could lead to a 5% overall increase in household income while increasing crop security and reducing food poverty. Farmers typically sell their beans after harvest when prices are low. As well as supporting natural enemies of field pests some field margin plant species will be admixed to stored beans enabling longer-term storage of beans worth up to 2 times more when supplies later in the year are depleted. The proposed project is directly and primarily relevant to the problems of the target developing countries and therefore is compliant with the OECD Overseas Development Assistance criteria. The action will be undertaken with the promotion of the economic development and welfare of developing countries as its main objective and seeks to develop zero cost interventions that increase yield and crop quality so are well suited and relevant to current farming strategies in bean production. Currently the project is undertaking research towards obtaining the information required to progress farming towards more ecologically approaches that deliver better yields. However, the evidence for this will not be produced until later in the project. We are still collating information on improved farming methods that consider the benefits of the field margin plants and invertebrates.

7. Project support to Gender equity issues

In our baseline survey the impact of enhanced biodiversity on bean production and poverty alleviation evaluated through surveys of 400 farmers in Tanzania and Malawi according to established measures, disaggregated for gender. Women are the primary growers of crops like beans (http://www.researchintouse.com/nrk/RIUinfo/PF/CPP28.htm#L3) so by addressing the production of beans through environmentally benign approaches to yield increase this project is directly addressing women in agriculture. We will be particularly mindful of gender as the baseline survey data is assessed in light of the project aims. Of the farmers interviewed so far in the baseline survey 76% are women. These will be the same farmers engaged in project training in year two or 3. The survey also revealed that the adult female in the household was the sole or joint decision-maker about how the harvested beans are used in 88% of households, and the sole or joint decision-maker about how the income from harvested beans are used in 86% of households, indicating that yield increases provide women with income, which is reportedly spent on female children in 48% of households.

8. Monitoring and evaluation

We are using a theory of change to monitor and evaluate the project success with respect to impact on livelihoods. The theory of change assumes that the farmers currently have inadequate knowledge and skills on how to control pests and, consequently, struggle to achieve increased bean productivity and quality through the exploitation of their ecosystems. The overarching measures of achievement will be based on how this knowledge has changed over the course of the project and whether farmers can implement changes to their farming practise that enhance ecosystem service delivery. Through the project, the farmers will be provided with information and knowledge on managing pests and improving their bean yield and quality. Therefore, the first module to be tracked by the survey will be the initial level and gradual improvement over time in the farmers' knowledge and attitudes.
It is believed that once the farmers' knowledge and attitudes have been enhanced, then they will gradually adopt sound farm management practices which could result in improved yield and quality of beans in their farms. Therefore the second module to be tracked by the surveys will be improvements in the farm management practices employed by the farmers. The theory of change then assumes that the sound farm management practices will lead to an improvement in the yield and quality of beans produced from the farms. Therefore, the third module to be tracked through the surveys will be the yield; while the fourth module to be tracked will be the quality, of beans produced from the farms. The theory of change then concludes that the improved bean yields and quality will lead to improved livelihood, living standards and general welfare of the farmers and their families. Therefore, the current status and longer-term outcome changes in livelihood, welfare and living standards of farmers and their families will be tracked through the surveys. Monitoring of activities and outputs is being conducted monthly using the project log frame.

9. Lessons learnt

Owing to the delay in appointment of students some of the training and survey work has been slower to get underway and this required a reallocation of funds from year one to year two and three which was agreed 6 months ago. It is easy to approach a project with high expectations of achievement for year one when in fact much of year one is spent getting activities planned. However none of the problems we have encountered are unusual for the kind of field work we are undertaking. We have established some targets and implementation plans which should ensure that the project progresses effectively. We are still largely on target to meet project output and outcomes.

The process of recruiting PhD students ended up being dependent upon securing money from the McKnight Foundation (which happened in the end). However, this was not approved until September – 6 months into the project so the delay in getting the project underway was exacerbated by this. However agreement with the

[14] Kalyebara, 2005, *African Crop Science Conference Proceedings,* 7: 967-970

DI to move some funding from year 1 to years 2 and 3 during the year has helped rebalance spending. If we had to do it again I would enquire if possible that the project was permitted to run across a timeframe that matched the crop in the field.

10. Actions taken in response to previous reviews (if applicable)

N/A

11. Other comments on progress not covered elsewhere

Owing to the seasonal nature of the target crop the April to April project time frame is not ideal. Planting starts in February in Tanzania so year 1 progress was limited to the tail end of a crop and the beginning of another. Also the time between approval and starting a project is very short giving little time to set up and organised budgets and funding allocations to partners who can do very little without the money.

12. Sustainability and legacy

Local scientists trained in invertebrate and plant identification and collections based science. Insectary and herbarium established at NMAIST to provide academic project legacy. Outreach activities including farmer field schools with distribution of information briefs in local languages will maximise this DI investment and ensure the project leaves a lasting legacy. By supporting small-scale bean production through strategies that enhance biodiversity in Tanzanian and Malawian agriculture the project will ensure that DI funding has a significant impact for poverty reduction, human welfare and conservation.

High-level capacity development of a PhD and Masters candidates to become leaders and change-agents, able to work on related projects and address other agricultural challenges. The advanced training in research skills, allied to joint publications in international journals and presentations at scientific conferences, will make the African scholars competitive for funding schemes to further their professional development in the EU and Australia e.g., the Australian Government's Endeavour Scheme[15].

Bean production is a growth sector in Tanzanian and Malawian Poverty Reduction Strategy Papers but cultivation is threatening ecosystems. Making bean production more efficient and benefiting more from those ecosystems will improve understanding of the importance of ecosystems for bean production and agriculture. This project will address poverty reduction and biodiversity conservation and support both countries CBD commitments. Nationwide agricultural policies that encourage ecosystem health and the maintenance of biodiversity that support and enrich agricultural yields, ensuring greater food security and improved livelihoods for resource limited farmers.

Our original exit strategy is still valid. However, there are challenges to leaving a sustained legacy in farming systems and adoption of new approaches to farming in a short space of time. Influencing sustained change in land-use practices is complex and requires strong, convincing evidence coupled with positive engagement and sustained support. Our approach to achieving this in the communities will develop through our surveys and interventions with farmers in our survey locations in the coming two years. Long-term uptake must become self-sustaining without reliance on such structures, we consider the priority in the short term to be maximising the likelihood of success of the 'demonstration' projects upon which future uptake will be built, and communicating those successes effectively as they are achieved. We are now working to engage these approaches into governmental programmes with the scope for future large-scale multiplication.

13. Darwin Identity

All communications regarding the project, both in Tanzania and Malawi and elsewhere make specific reference to Darwin Initiative funding (as a distinct project) and these will include a project blog posts. Year one has been a quiet in terms of publicising the project but now the project is up and running in all areas we will endeavour to make more outputs in the public domain. Some information has been provided through Twitter. @chickpeaman. In year 2 we will establish a fixed web presence through a project website that will used for sharing information and publicising the work. Within country for the partners and in all communications with representatives of the CBD, and other conservation organisations there is a clear understanding of the Darwin Initiative and its role in supporting this action within in the host country.

[15] https://aei.gov.au/scholarships-and-fellowships/pages/default.aspx

14. Project Expenditure

Table 1 Project expenditure <u>during the reporting period</u> (1 April 2015 – 31 March 2016)

Project spend (indicative) since last annual report	2015/16 Grant (£)	2015/16 Total Darwin Costs (£)	Variance %	Comments (please explain significant variances)
Staff costs (see below)			2%	Malawi contribution not sent owing to local change in staff.
Consultancy costs			-22%	More time was needed to establish the survey locations.
Overhead Costs			-1%	Due to overspend in staff costs
Travel and subsistence			8%	Cheaper hotels and tickets
Operating Costs				
Capital items (n/a)				
Others (see below)			59%	Hold ups in issuing permits for in country work
TOTAL				

Some of the year one budget was reallocated to years 2 and 3 through agreement with the DI as a consequence of recruiting the PhD students so late.

Original allocation for this budget was 3,487 but we only spent 1438. This is largely due to the fact that we frontloaded the project to get all the equipment we need and particularly the permits fro working in country. However, these permits are only issued annually meaning we need to purchase them every year. It would be very helpful if we could carry this under spend from year 1 to continue to invest in the permits and equipment as required.

Please provide a description of the 'other' items funded under this year's Darwin Initiative grant. Add other rows if necessary.

Other items – description	Other items – cost (£)
Entomological and botanical equipment for field surveys	
Conference fees	
Bank Charges	
Travel Permits	
Field Equipment and Stationery for PhD students	
TOTAL (Must match Others total in Section 6)	**1,438.18**

Annex 1: Report of progress and achievements against Logical Framework for Financial Year 2015-2016

Project summary	Measurable Indicators	Progress and Achievements April 2015 - March 2016	Actions required/planned for next period
Impact The harnessing of agricultural biodiversity in bean production systems of East Africa established and implemented widely to improve food security, reduce poverty and increase ecosystem resilience.		Surveys underway, training provided and potential value of ecosystems services to food production shared with >200 farmers through baseline survey	
Outcome Smallholder farmers implement science-based methods for enhancing and restoring ecosystem services and biodiversity in agricultural systems that improve bean yield and quality, food security and rural livelihoods.	Roles and interactions of key plant and beneficial invertebrate species of agricultural ecosystems understood by farmers and agricultural technicians by end of project.	In progress but requires considerable further preparative work in surveys and analysis first.	Continue surveys and analysis of interactions of insects and plants.
	Management methodologies that maintain ecosystem services and augment natural pest enemies and pollinators developed and implemented to increase yields by 20% from baseline data at project outset without additional agricultural inputs.	IN progress but requires considerable further preparative work in surveys and analysis first.	Continue surveys and analysis of interactions of insects and plants.
	Bean crop productivity and quality improved and monetary value of beans increased for 400 farmers by 20% by project end	in progress but requires considerable background information from surveys which are underway and their analysis first. 200 farmers already engaged through baseline survey	Continue surveys and analysis of interactions of insects and plants.
	Role of agricultural biodiversity in crop quality, enhanced yield and consequent poverty alleviating benefits demonstrated to key stakeholders through participatory field trials.		

	Yield and poverty impacts of enhanced biodiversity demonstrated through individual farmer surveys for bean production at project outset and project end that indicate increased income of 5-10% per household	
Output 1. Ecosystems and plant species that are habitats for key natural enemies of bean pests identified.	1.1 Plant biodiversity surveys undertaken across 25 farm locations in Arusha and Moshi by year 2 1.2 Insect diversity surveys undertaken 25 farm locations in Northern Tanzania by year 2 1.3 Associations between habitat type and plant of invertebrate species diversity established by end of year 2. 1.4 Plant species of importance to beneficial insects and with pesticidal properties identified	Surveys conducted at 4 locations for insect diversity and data analysed as reported above and in Annexe 4. Plant and invert surveys underway at 24 other locations in Tanzania. On course to complete surveys and make associations between the occurrence of plant species and beneficial insects during year 2.
Activity 1.1 Plant surveys to determine botanical biodiversity across 3 ecological zones undertaken across 25 farm locations in Arusha and Moshi.		Plant surveys underway in 24 locations at 3 zones.
Activity 1.2, Invertebrate surveys to determine biodiversity among pollinators, natural enemies and pests across 4 ecological zones and undertaken across 25 farm locations in Arusha and Moshi, N. Tanzania.		I survey undertaken at 4 locations in Tanzania as early pilot. Further invert surveys underway in 24 locations at 3 zones with for invertebrates undertaken already.
Activity 1.3 Plant species occurrence and agroecosystem type correlated to establish key species in different locations.		Not done – waiting analysis of plant species.
Output 2. Key invertebrate pollinators of beans and their key habitat (plants/ecosystems) established at 25 locations in 4 agro-ecological zones.	2.1 5 most important/abundant natural enemies of bean pests and their most important plant species habitats identified and target pest species determined by start of year 3. 2.2 5 key/abundant pollinators of beans and their most important non-crop species habitats identified by start of year 3. 2.3 5 most important pests identified and	Surveys underway in different locations in Tanzania and some progress on surveys made in Malawi.

	their most important non-crop habitats established through abundance, perceived impact and literature. 2.4 Habitat quality index developed to assess relative risk and provisioning in habitat for supporting beneficial invertebrates	
Activity 2.1. Natural enemies of bean pests will be identified across experimental locations and the most important plant species identified and suitability of key plants species as habitat/refuge determined in laboratory and glass house experiments		Not complete – awaiting completion of insect survey
Activity 2.2. Target pest species determined and likely natural enemies will be evaluated.		Not complete – awaiting completion of insect survey
Activity 2.3. Insect surveys will be undertaken to identify the main pollinators of beans and through literature and field studies the most important plant species habitats determined across seasons to identify likely habitat outside the growing seasons.		Surveys underway in different locations in Tanzania and some progress on surveys made in Malawi
Activity 2.4. Key pests species are already known for beans in East Africa so this activity will identify which plant species provide field margin refuge and habitat for all life stages of key bean pests e.g. for adults of Lepidoptera where their larvae are key pests.		Not complete – awaiting completion of insect survey
Output 3. Capacity of 400 lead farmers increased by information and guidance on exploiting and maintaining agricultural biodiversity for improved crop yield..	3.1 Impact of field margin variation across bean production systems or ecological interventions on populations of natural enemies, pollinators and pest insects determined in year 1. 3.2 Baseline evaluation of productivity and bean quality of 400 farmers in Malawi and Tanzania determined by end of year 1. 3.3 Field trials conducted to determine impact of field margin variation across bean production systems on bean yields and bean quality in year 2. 3.4 Impact of pollinators on bean yield	Baseline survey undertaken in Moshi – currently 100 farmers interviewed using a questionnaire indicated in annex 4 and data being analysed. Other indicators in this Output await being informed by the survey. However initial findings of survey suggest much room for improvement. Farmers are using various synthetic pesticides but their uses have some limitations. E.g., they can't be used during flowering stage because its poison can last for a long time even after harvest that makes bean seeds poisonous to consumers (but this will also kill pollinators). During short rain season (July-October) it's not suitable for maize as they use irrigation system and the water is not enough for both maize and beans. Synthetic pesticides have health problems as it's toxic and according to farmers, it causes flue and breathing problems when sprayed as the farmer doesn't wear protective gear. Some farmers are using both plant (especially leaves of neem trees) and organic (especially ashes and cattle's urine). However, they said that it is time consuming to

	and quality evaluated as a percentage improvement for each ecosystem and across the whole experimental area. 3.5 Impact of changes in field bean ecosystem biodiversity on livelihoods evaluated through post field trial surveys, monitoring benefits to farmers' livelihoods including effects on financial wealth, nutrition and health. 3.6 Impact of ecosystems on bean production disseminated to 3600 farmers through fields school and provision of information leaflets	prepare especially plants and not as effective in eradication of insect pests so they also need to spray some cc of synthetic pesticides to protect your crops from pests. Most of the farmers are not aware about natural enemies. Some farmers don't know even the common pollinators such as bees. From the pictures shown, they identified the natural enemies as insect pests. Most of the farmers identified ladybird beetle shown in the picture as the pest Ootheca. Most farmers have seen the insect pests in their farms but they don't know their names. Most farmers don't know the importance of field margins in terms of harbouring beneficial insects. They think field margins harbour only insect pests and that's why most of them clear field margins and leaving only trees, and some time they spray weed killer or burn field margin plants. Farmers practice either mono cropping or mixed cropping mainly due to season or insufficient land. Some farmers use synthetic pesticides though the names of the pesticides they don't know because when they go to the agro-vet shops, they just explain what is happening with their crops and then the seller will advise on the appropriate pesticides to be used. Sometime farmers can collect a representatives of insect pests which attack their beans and show to agro-vet specialists so that they can get appropriate pesticides. Some bean varieties such as Soya njano has been mentioned by most of the farmers as one of bean varieties harbouring more insect pests though it is grown by most of them just because of its good price in the market. Most farmers claimed the need of agricultural education so as to apply best agricultural practices that will help to increase bean production.
Activity 3.1 and 3.2 Baseline evaluation of productivity and bean quality of 400 farmers in Malawi and Tanzania determined and Baseline field survey of the variation across bean production systems or ecological interventions on populations of natural enemies, pollinators and pest insects.		Underway with primary findings summarised above ad full report in annex.
Activity 3.3 – 3.5		Activity not complete.
Output 4. Field margin plant species that support beneficial insects evaluated for their biological activity against pest insect species of beans and negative effects on natural enemies and pollinators determined.	5 Plant species of potential importance as habitat and refuge for beneficial insects and with potential pesticidal properties identified. Plant species of potential value as pesticidal evaluated in laboratory and screen-house trials for efficacy against pests and effects against two key natural	This activity is primarily for year two although some preliminary assessment of some field margin species have been undertaken including on *Bidens pillosa* a potentially importantly forage provision for pollinators.

	enemies determined by end of year 2. Pesticidal efficacy of plants evaluated in laboratory and screen-house against two key natural enemies. Farmer field trials evaluating efficacy of pesticidal plants to control bean pests and effects against key natural enemies and pollinators by end of year 3. Potential of pesticidal plants to increase production and bean quality evaluated through impact assessments in year 3	
Activity 4.1 – 4.4 During surveys species that are known through associated actions (See Q 15) field margin plant species of potential importance as habitat and refuge for beneficial insects but that also have pesticidal properties will be identified. Pesticidal plants evaluated in laboratory and screen-house trials for efficacy against 3 pest species determined Pesticidal efficacy of plants from Activity 4.2 will be evaluated in laboratory and screen-house against two key natural enemies. Farmers in Tanzania and Malawi will be provided protocols to pesticidal plants to control bean pests and effects against key natural enemies and pollinators. Impact of pesticidal plants technologies to increases production and bean quality evaluated through impact assessments		Some minor progress but these activities really for Year 2 once plant surveys complete.
Output 5. Post-graduates trained in conducting biodiversity surveys and carrying out field and laboratory based research.	At least 10 post graduate students trained and provided field experience in conducting botanical biodiversity surveys by end of project At least 10 post graduate students trained and provided field experience in conducting invertebrate surveys biodiversity surveys by end of project One PhD student provided training in laboratory and field evaluation of suitability of at least two plant species and	Three MSc student were recruited on to he project at the outset ad received training in various aspects of plant and invertebrate surveys and evaluation of efficacy of plants in field against pests. Some work published subsequently (see above). 2 PhD students recruited and trained up in survey techniques and will continue to receive training.

two key beneficial insects by end of year 3	
Activity 5.1. All plant diversity surveys will be undertaken as field trips for post graduate students on the Biodiversity and Ecosystems MSc at NMAIST providing training for 10 students in field collection in identification techniques as well as collection establishment	This activity is underway and reported in some detail above. As the season crosses from Feb – June they are not yet complete.
Activity 5.2.. Invertebrate diversity surveys will be undertaken as field trips for post graduate students on the Biodiversity and Ecosystems MSc at NMAIST providing training for up to 10 students in field collection techniques and identification and naming while a digital record of all taxa collected will be made	This activity is underway and reported in some detail above. As the season crosses from Feb – June they are not yet complete.
Activity 5.3 PhD student will be supervised to undertake training in specific laboratory and field evaluation of plants that determine the suitability of at least two plant species and two key beneficial insects that could be targets for ecological interventions. It is expected that this work will lead to information that identifies potential targets for propagation and distribution among bean farmers as a key environmentally benign input to improve production	This activity is underway and reported in some detail above. Student will continue to receive training in various aspects of plant abd invertebrate biology throughout the project.

Annex 2 Project's full current logframe as presented in the application form (unless changes have been agreed)

Project summary	Measurable Indicators	Means of verification	Important Assumptions
Impact: The harnessing of agricultural biodiversity in bean production systems of East Africa established and implemented widely to improve food security, reduce poverty and increase ecosystem resilience.			
Outcome: Smallholder farmers implement science-based methods for enhancing and restoring ecosystem services and biodiversity in agricultural systems that improve bean yield and quality, food security and rural livelihoods.			
Outputs: 1. Ecosystems and plant species that are habitats for key natural enemies of bean pests identified.	1.1 Plant biodiversity surveys undertaken across 25 farm locations in Arusha and Moshi by year 2 1.2 Insect diversity surveys undertaken 25 farm locations in Northern Tanzania by year 2 1.3 Associations between habitat type and plant of invertebrate species diversity established by end of year 2 1.4 Plant species of importance to beneficial insects and with pesticidal properties identified	1.1 -1.4 Research paper published in international refereed journals reporting plant and insect biodiversity surveys and associations between habitat type and plant of invertebrate species diversity	Bean ecosystems at least in some locations provide adequate diversity (i.e. have not already been degraded) to prevent meaningful biodiversity assessments in adequate locations. Mitigation: During the IPM workshop funded my McKnight earlier in 2014 from which this project idea arose – the participants visited two field locations to make a pilot assessment. This suggested that at least in two ecological zones in our target area that plant species showed some diversity and both natural enemies and pollinators occurred in measurable numbers to enable a meaningful evaluation of biodiversity across the region.
2. Key invertebrate pollinators of beans and their key habitat (plants/ecosystems) established at 25 locations in 4 agro-ecological zones.	2.1 5 most important/abundant natural enemies of bean pests and their most important plant species habitats identified and target pest species determined by start of year 3. 2.2 5 key/abundant pollinators of beans and their most important non-crop species habitats identified by start of year 3. 2.3 5 most important pests identified and their most important non-crop habitats established through abundance, perceived impact and literature. 2.4 Habitat quality index developed to assess relative risk and provisioning in habitat for supporting beneficial invertebrates	2.1-2.3 Research paper published in international refereed journals indicating most important invertebrates and their most important plant species habitats. 2.4 Habitat quality index used to quantity diversity and incorporated in paper indicated in 2.1 as methods component	Extreme weather conditions will not affect biodiversity sampling. Mitigation: Sampling will be undertaken across three seasons and at different times of the year – both during the cropping period and outside the cropping period to ensure that extreme weather events will not affect all data collection
3. Capacity of 400 lead farmers increased by information and guidance on	3.1 Impact of field margin variation across bean production systems or	3.1 Project report showing impact of field margin species	Farmers commissioned to undertake independent field activities that evaluate various

exploiting and maintaining agricultural biodiversity for improved crop yield.	ecological interventions on populations of natural enemies, pollinators and pest insects determined in year 1. 3.2 Baseline evaluation of productivity and bean quality of 400 farmers in Malawi and Tanzania determined by end of year 1. 3.3 Field trials conducted to determine impact of field margin variation across bean production systems on bean yields and bean quality in year 2. 3.4 Impact of pollinators on bean yield and quality evaluated as a percentage improvement for each ecosystem and across the whole experimental area. 3.5 Impact of changes in field bean ecosystem biodiversity on livelihoods evaluated through post field trial surveys, monitoring benefits to farmers' livelihoods including effects on financial wealth, nutrition and health. 3.6 Impact of ecosystems on bean production disseminated to 3600 farmers through fields school and provision of information leaflets	variation on bean production. Website produced to provide global reporting vehicle and networking tool. 3.2 Project report evaluating baseline productivity and bean quality of farmers in Malawi and Tanzania determined by end of year 1 – farmers survey reports. 3.3 Project report of Field trials conducted to determine impact of field margin variation on bean yields and bean quality – farmer survey reports. 3.4 Research paper reporting Impact of invertebrates on bean yield and quality evaluated as a percentage improvement across experimental area. 3.5 Impacts on wealth, nutrition and health incorporated in to paper in 3.4. 3.6 Production of 4000 information leaflets on the role of ecosystems in bean production. Policy briefs produced for high level audience. Radio interview and Newspaper stories.	technologies that arise from biodiversity surveys conduct those evaluations effectively and without resorting to the use of pesticides. Mitigation: At the outset of farmer trials and during the course of the cropping season farmers will be visited regularly to encourage and enforce the specific requirements for those field trials. Farmers will be provided clear guidance on how to conduct field trials.
4. Field margin plant species that support beneficial insects evaluated for their biological activity against pest insect species of beans and negative effects on natural enemies and pollinators determined.	4.1 5 Plant species of potential importance as habitat and refuge for beneficial insects and with potential pesticidal properties identified. 4.2 Plant species of potential value as pesticidal evaluated in laboratory and screen-house trials for efficacy against pests and effects against two key natural enemies determined by end of year 21. 4.3 Pesticidal efficacy of plants evaluated in laboratory and screen-house against two key natural enemies. 4.4 Farmer field trials evaluating efficacy of pesticidal plants to control bean pests and effects against key natural enemies and pollinators by end of year 3. 4.5 Potential of pesticidal plants to increase production and bean quality evaluated through impact assessments in year **3**.	4.1-4.3 Research paper in international journal published reporting results. 4.4 Farmer field trials evaluating efficacy of pesticidal plants to control bean pests and effects against key natural enemies and pollinators by end of year 3. 4.5 Impact of pesticidal plants technologies to increase production and bean quality evaluated through impact assessments in year 3	
5.Post-graduates trained in conducting biodiversity surveys and carrying out	5.1 At least 10 post graduate students trained and provided field experience in conducting	Graduate theses produced and research papers published by	

field and laboratory based research.	botanical biodiversity surveys by end of project. 5.2 At least 10 post graduate students trained and provided field experience in conducting invertebrate surveys biodiversity surveys by end of project. 5.3 **Two** PhD student provided training in laboratory and field evaluation of suitability of at least two plant species and two key beneficial insects by end of year 3	students reporting results. PhD thesis produced and interim reports	

Activities (each activity is numbered according to the output that it will contribute towards, for example 1.1, 1.2 and 1.3 are contributing to Output 1)

Output 1

Activity 1.1	Plant surveys to determine botanical biodiversity across 3 ecological zones undertaken across 25 farm locations in Arusha and Moshi.
Activity 1.2	Invertebrate surveys to determine biodiversity among pollinators, natural enemies and pests across 4 ecological zones and undertaken across 25 farm locations in Arusha and Moshi, N. Tanzania.
Activity 1.3	Plant species occurrence and agroecosystem type correlated to establish key species in different locations.

Output 2

Activity 2.1	Natural enemies of bean pests will be identified across experimental locations and the most important plant species identified and suitability of key plants species as habitat/refuge determined in laboratory and glass house experiments
Activity 2.2	Target pest species determined and likely natural enemies will be evaluated.
Activity 2.3	Insect surveys will be undertaken to identify the main pollinators of beans and through literature and field studies the most important plant species habitats determined across seasons to identify likely habitat outside the growing seasons.
Activity 2.4	Key pests species are already known for beans in East Africa so this activity will identify which plant species provide field margin refuge and habitat for all life stages of key bean pests e.g. for adults of Lepidoptera where their larvae are key pests.

Output 3

Activity 3.1	Baseline evaluation of productivity and bean quality of 400 farmers in Malawi and Tanzania determined
Activity 3.2	Baseline field survey of the variation across bean production systems or ecological interventions on populations of natural enemies, pollinators and pest insects.
Activity 3.3	Field trials will be carried out in Malawi and Tanzania (200 farmers in each country) that will evaluate how specific field margin plant and natural enemy invertebrate species contribute to improved bean yields and bean quality.
Activity 3.4	Impact of pollinators on bean yield and quality evaluated will be evaluated through target field trials comparing bagged versus unbagged species and across locations to compare the absolute impact of pollinators sand the relative service delivery of pollination across different locations that differ in their plant and invertebrate diversity.
Activity 3.5	Impact of changes in field bean ecosystem biodiversity on livelihoods will be evaluated through post field trial surveys that compare production and quality at field locations and monitor absolute changes to farmers' livelihoods including increases in income, nutrition and health.
Activity 3.6	Production and dissemination of information leaflets to 3600 households.

Output 4

Activity 4.1	During surveys species that are known through associated actions (See Q 15) field margin plant species of potential importance as habitat and refuge for beneficial insects but that also have pesticidal properties will be identified.
Activity 4.2	Pesticidal plants evaluated in laboratory and screen-house trials for efficacy against 3 pest species determined

Activity 4.3	Pesticidal efficacy of plants from Activity 4.2 will be evaluated in laboratory and screen-house against two key natural enemies.
Activity 4.4	Farmers in Tanzania and Malawi will be provided protocols to pesticidal plants to control bean pests and effects against key natural enemies and pollinators.
Activity 4.5	Impact of pesticidal plants technologies to increases production and bean quality evaluated through impact assessments
	Output 5
Activity 5.1	All plant diversity surveys will be undertaken as field trips for post graduate students on the Biodiversity and Ecosystems MSc at NMAIST providing training for 10 students in field collection in identification techniques as well as collection establishment.
Activity 5.2	Invertebrate diversity surveys will be undertaken as field trips for post graduate students on the Biodiversity and Ecosystems MSc at NMAIST providing training for up to 10 students in field collection techniques and identification and naming while a digital record of all taxa collected will be made.
Activity 5.3	A PhD student will be supervised to undertake training in specific laboratory and field evaluation of plants that determine the suitability of at least two plant species and two key beneficial insects that could be targets for ecological interventions. It is expected that this work will lead to information that identifies potential targets for propagation and distribution among bean farmers as a key environmentally benign input to improve production.

Annex 3 Standard Measures

Table 1 Project Standard Output Measures

Code No.	Description	Gender of people	Nationality of people	Year 1 Total	Year 2 Total	Year 3 Total	Total to date	Total planned during the project
1B	PhD students appointed	1 male 1 female	Both Tanzanian	2			2	2
2	MSc student to undertake Masters project [in progress]	2 male 1 female	All Tanzanian	3			3	8
6A	Farmers trained in using field margin plants for pest management	Min 50% female	Tanzanian and Malawian	0			0	400
11A	Papers published peer review journals	One male one female senior author.	Tanzanian and UK	2			2	4
11B	Papers submitted peer review journals							
12 B	Specimen databases enhanced in Tanzania			1				2
13 B	Malawian and Tanzanian species reference collections enhanced (botanical collections)			1			1	2
13 B	Malawian and Tanzanian species reference collections enhanced (insect collections)			1			1	2
14A	Conferences/seminars/workshops organised to disseminate findings			0			0	2
14B	Conferences/seminars attended to disseminate findings			0			0	4
15	National press releases in Bolivia and UK			0			0	3
16	Newsletters (including web-based blog posts, and website news items)			0			0	5
18	National TV programmes Bolivia and UK, including YouTube video clip)			0			0	3
20	Estimated value (£'s) of physical assets to be handed over to host country			1500			1500	5000
22	Permanent field plots established			24			24	25
23	Value of resources raised as indicated in proposal including in kind							

	McKnight Foundation			£75,000			£75,000	£75,000
	Charles Sturt University			£11,000			£11,000	£34,000
	Natural Resources Institute			£7,222			£7,222	£20,982
	Total						£93,222	£129,982

Table 2 Publications

Title	Type (e.g. journals, manual, CDs)	Detail (authors, year)	Gender of Lead Author	Nationality of Lead Author	Publishers (name, city)	Available from (e.g.weblink or publisher if not available online)
The Potential of Common Beneficial Insects and Strategies for Maintaining Them in Bean Fields of Sub Saharan Africa	Journal	**Ndakidemi**, B. Mtei, K., **Ndakidemi**, P.A., **2015**	M	Tanzanian	Scientific Research Publishing Inc.	http://file.scirp.org/pdf/AJPS_2016031015420060.pdf
Field margin weeds provide economically viable and environmentally benign pest control compared to synthetic pesticides	Journal	**Mkenda, P.,** Mwanauta' R., **Stevenson, P.C. Ndakidemi' P.**, Mtei, K., and **Belmain, S.R**. **2015**	F	Tanzanian	Public Library of Science (*PLoS One*)	http://dx.doi.org/10.1371/journal.pone.0143530
		Project partners indicated by embolden				