Exploring how a blended approach of ecology, culture and technology can help translate nature-based solutions for pest-control into crop farming for African subsistence farming communities.

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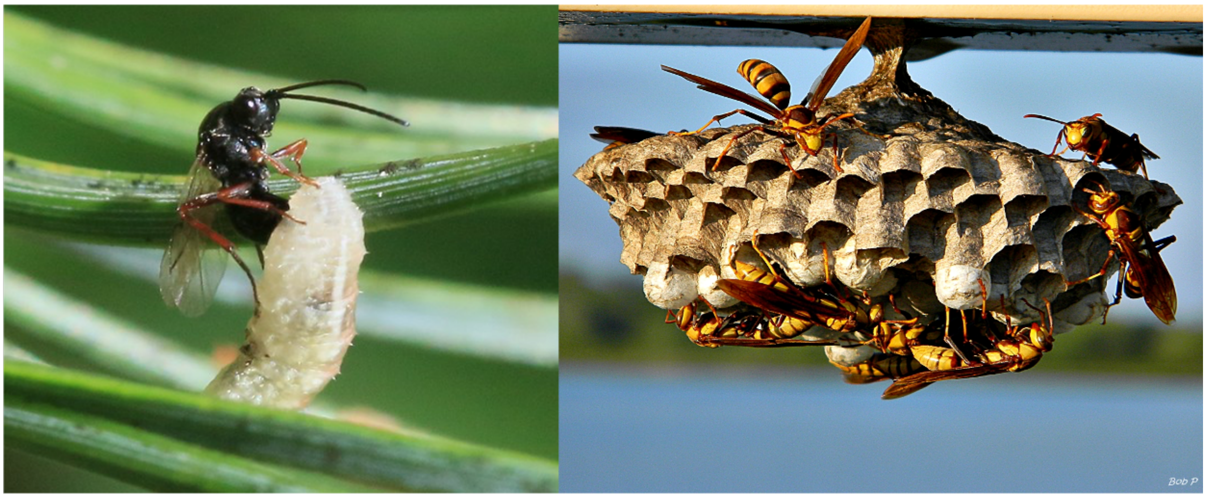

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TABLE OF CONTENTS

1. Executive Summary

Problem: Global food supplies are not sufficient to sustain the planet's growing human population. Crop pest management is of paramount concern: arthropod pests cause losses of 18–26% annual crop yield worldwide, at an economic cost > US$ 470 billion. Current use of chemicals to control pests is unsustainable for human health, biodiversity, and climate change. The impact is especially acute in low/middle income countries (LMICs) like Nigeria and Ghana, where population growth and poverty are substantial, and >80% of farming is subsistence-level. These countries are being left behind as climate-smart methods of pest control, as used in countries like UK and Brazil, are currently unviable for LMIC farmers. Unregulated pesticides are often used; as well risks to biodiversity and human health, these chemicals can also drive inequality as 75% of agricultural labour in African small-holder farms is conducted by women, who then suffer detrimental health impacts from exposure. There is an urgent need for innovations in sustainable pest control methods that are accessible and culturally appropriate for subsistence farmers in LMICs, safe for biodiversity and human health and that afford resilience to local communities coping with climate change.

Solution: Natural enemies are insects that naturally predate on arthropod pests. Africa is host to a huge diversity of natural enemies, especially parasitoids and hunting arthropods which are known to be effective regulators of crop pests. Brazil's crop production has a strong industry-led infrastructure in production of natural enemies for pest-control; the UK has a strong government-led initiatives in the use of ecological practices to encourage natural enemies and pollinators in crop farming. This scoping project explored the potential for translating these approaches into African subsistence farming, in a way that can be maintained by communities, and which accounts for diverse cultural and knowledge-bases.

Outcome: This Project assembled and consulted a Network of 70 representatives from the UK, Brazil, Ghana and Nigeria, capturing the voices across diverse sectors, including agriculturalists, sociologists, ecologists, policy-makers, industrial partners and farmers. Through our Networking activities (including on-site visits, in-person and on-line meetings and workshops) we identified the perceived challenges, opportunities and barriers faced in translating methods of natural enemy-led pest-control into West African small-holder crop farming communities. The opportunities for commercial development of parasitoids as sustainable biocontrol agents are substantial with realistic potential for success, due to existing on-scale rearing methods developed in Brazil and the local knowledge-base and ambition across all interested parties in West Africa. Research from Brazil and the UK has shown that social wasps can be effective pest controllers of fall army worm and sugarcane borer, and can be managed in the field through the use of vespiaries. Opportunities for integrating social wasps into pest management in West Africa are promising due to the rich local biodiversity of wasps; demonstrating their effectiveness within fields is a key priority to provide the fundamental research, assessment of economic viability, training and proof-of-concept demonstration plots are required to shift the negative perceptions of farmers towards these stinging insects. Community engagement was identified as a central challenge for both approaches; success of either method is likely to be enhanced by habitat regeneration efforts to improve the chances of these natural enemies persisting as self-sustaining populations within a balanced ecosystem.

Conclusion: Both parasitoid wasps and social aculeate wasps hold much potential for use as biocontrol agents in small-holder crop farming in West Africa. Implementation of parasitoids, habitat regeneration and community engagement are recognised essential for their successful implementation as part of an integrated pest management programme. These approaches are the potential to address directly the three main pillars of Climate-Smart Agriculture by: sustainably increasing agricultural productivity and income; providing a form of pest control that can be adaptive and resilient to climate change; and that reduces greenhouse gas emissions, to be implemented within a gender-responsive framework.

2. Background

Insect crop pests are one of the major threats to food security and economic development worldwide, and climate change is likely to exacerbate this, as species ranges shift with changing conditions. Current pest management – particularly the use of pesticides – is unsustainable due to impacts on human health and the environment; moreover, pests are increasingly evolving resistance to these chemicals. This is especially worrying for subsistence farmers and small producers, who are extremely vulnerable to crop damage, exacerbated by climate change, particularly in West Africa. Farmers report losing high proportions of their crop yields, which has direct detrimental impacts on their livelihoods, heath and quality of life. Despite being aware of the health risks, most farmers use chemical pesticides: they are quick and easy to apply, and are often promoted by governments because the alternative (uncontrolled pests) spells a humanitarian disaster.

There is an urgent call for innovations in more sustainable forms of pest control. Natural enemies - such as arthropod predators or insect-targeting fungi – are an example of such sustainable methods. Harnessing the predatory and/or parasitic behaviours of native species, along-side augmentation of natural habitats, promises to be a mode of pest control that can be resilient to climate change as well as safe for humans and the environment.

This report focuses on two leading avenues of biocontrol using arthropod natural enemies in small-holder farms in West Africa:

(1) Introduction and/or augmentation of parasitoid wasps through Integrated Pest Management (IPM). Parasitoid wasps are small insects that oviposit their eggs in or on another arthropod, leaving their larvae to develop on the host which they ultimately kill. They can be mass-reared and released into pest-affected areas. This approach is already well-established worldwide for various parasitoids of different crop pests, particularly in Brazil, where the market for this technology is rapidly developing. There is scope to upscale these productions in West Africa for more widespread distribution using knowledge and experience accrued by Brazilian partners.

(2) Use of arthropod natural enemies (i.e. predatory, hunting insects), with a focus on social wasps. Social wasps are central-place foragers that scavenge or hunt arthropod prey to bring back to their nests to feed to their offspring. Social wasps are known to hunt crop pests such as Fall Army Worm (FAW) caterpillars in West Africa and Brazil; husbandry of these insects is not well developed but is not dissimilar to husbandry of honeybees. These insects show great potential to act as complementary agents of biocontrol to other methods; however, research gaps exist that require attention before these methods can be implemented on scale.

With Brazil as a model for sustainable methods of biocontrol, thus we aimed to understand and summarise the research gaps, opportunities for innovation and associated challenges across Ghana and Nigeria. We collated an international interdisciplinary Network of researchers (entomologists, ecologists, sociologists, agronomists), business innovators, policy makers and community representatives to gain a better understanding of the challenges and opportunities related to pest control in these areas. We convened in-person and online meetings, networking events and in-country visits to facilitate information transfer among stakeholders.

Our main findings show that there is high potential and scope to implement both methods in West Africa, particularly in Ghana.

(1) **Commercialisation of parasitoid wasps.** The Ghanaian governmental runs a parasitoid facility in southern Ghana where it is conducting field trials, the parasitoids are not readily available to farmers and has not been commercialised. There is interest among many of the major stakeholders in Ghana to develop these technologies in Ghana, however there are some major barriers, including need for

initial investment, demonstration plots, training and changes in farmer mindset. Additionally, it is crucial to consider the impacts of introduced parasitoids on native insect populations, which could have the potential to disrupt essential ecosystem services.

(2) **Research on pest-control potential of social wasps.** Social wasps are abundant in West Africa and recent research confirms they hunt crop pests; they have high potential to be complementary to other biopesticides, including parasitoid wasps, as they are likely to target different pest life-stages. There was considerable interest among researchers to develop this knowledge base. There are also some challenges to overcome: i) demonstrations of the effectiveness of wasps in-situ remains outstanding; ii) social wasps are often associated with fear and hatred, thus perceptions must be changed through engagement, education and training.

(3) **Habitat regeneration and maintenance:** Both methods, if further developed, must be implemented alongside agroecological practices: this occurs when social and ecological management practices are applied to agriculture to maintain essential ecosystem services, such as soil regeneration, encouraging native vegetation to provide shade, nesting sites and nutritional resources. This is essential in order that natural enemy populations can persist

3. Opportunities for using natural enemies for climate-smart pest control in West Africa

This section outlines the key opportunities for using natural enemies as identified by the Network, through discussions and examination of the literature. It is not intended as a comprehensive review, but rather a representation of the Network's collective knowledge, opinions and expertise, as relevant to Ghanaian and Nigerian farming systems.

3.1 General Opportunities

Existing Natural Habitats. One of the key challenges in sustainable farming innovations is how to (re)establish natural ecosystems which can provide refuges and reservoirs for natural enemies, pollinators and other beneficial wildlife, and help maintain ecosystem functions. Globally, natural habitats that provide such refuges and reservoirs are declining rapidly, with remaining areas increasingly reduced, fragmented and often isolated as islands within agricultural monocultures. Agroforestry development alongside a shift away from agrochemicals is a promising approach; but regeneration of patches of native, wild ecosystems takes time, and initiation of entirely new ecosystems is even slower. An opportunity to tackle this problem are through other remaining areas of intact habitat, including sacred forests; these are forests with religious or cultural significance to local communities, which are typically situated around a point of worship or ceremonial ground, and managed by local people.

3.2 Parasitoids – Specific Opportunities

Technological infrastructure in Brazil. Brazil is a world leader in biocontrol technologies, benefiting from decades of investment. There is substantial demand for more sustainable technologies, due to extensive agriculture, pesticide resistance and need for more environmentally sustainable alternatives. Two of the most popular pest-control methods currently employed in Brazilian agriculture are parasitoid wasps and fungi. These natural enemies are highly efficient in controlling pests if applied appropriately and are now used in major commercial ventures across Brazil. In response to this, the market for these natural enemies has grown significantly in recent years, with the use of these biocontrol agents having increased by >20% in the last decade in Brazil alone. Despite this, demand remains higher than current supply. Brazil is well-placed to provide knowledge and expertise to West African countries in the development of parasitoid rearing facilities on-scale, and scoping the business model for tapping into this emerging market.

Knowledge-base in Ghana/Nigeria. West Africa is currently facing similar issues to Brazil, with respect to detrimental impacts of excessive pesticide use on the health of people and the environment; and pests evolving resistance to current control methods is an inevitable problem for the near future. There have been multiple parasitoid wasp releases across Africa as part of Integrated Pest Management (IPM) initiatives. This has focused on a variety of different crop pests and parasitoids. Most recently, interest has concentrated on the American invasive species, the Fall Army Worm (FAW) - a primary pest of maize, which has been spreading across Africa since its introduction in 2016. There are some good candidates for biocontrol of FAW including the parasitoid *Telenomus remus* (Scelionidae), which is already used commercially across the globe. Although it is not native to Africa, it is now found in Ghana and many other African countries, likely through the many releases for pest control in Africa and also through expanding populations of the parasitoid as it tracks the spread of FAW. Additionally, there are a further 18 known species of parasitoids which are known to be effective in control of FAW which occur in Ghana; however, their efficacy is less well known, and how to augment their populations to maximise their effectiveness (e.g. through rear and release, or habitat enrichment) is unknown.

Habitat restoration efforts. Because of the lack of infrastructure to produce parasitoids on-scale in Ghana, and because other (native?) parasitoids of FAW are already known to be present, most recent efforts to combat crop pests using natural enemies have focused on improving natural habitat for these natural enemies. There are on-going parasitoid rearing efforts in Ghana by PPRSD-MoFA that have resulted in successful small-scale releases of *T. remus* at research stations and small farms, where the parasitoids were supplied to farmers free of charge. To our understanding, in Nigeria there have been similar small-scale releases of parasitoids by the IITA; however, the results of these releases on crop pests are unclear. Thus, the evidence clearly demonstrates the potential demand for these parasitoids commercially for use in controlling FAW in West Africa, but up-scaling and impact are yet to be detailed.

3.3 Social Wasps – Specific Opportunities

Life-history. Social wasps are predators of insects and arthropods. They are quite generalist in their choice of prey, taking a wide range of taxa, but especially Lepidoptera, Diptera and Hemiptera – the insect orders to which many of the key crop pests belong. Social wasps are central-place foragers – meaning that they always return with their prey to a nest which can last several months or even a year in the more aseasonal regions. This means that one can be sure that the wasps are foraging within a certain home range (up to a few kms) of their nest. Their nests (with wasps and brood) are also amenable to being relocated, into a hive box (similar to honeybees) or reattached to a suitable substrate such as a simple shed or lean-to in a field, for example. Despite their reputation as dangerous, wasps can be worked with safely by the implementation of simple protective clothing and a home-made wasp hat. In short, where social wasps are abundant, they hold huge potential as biocontrol agents.

Evidence-base from Brazil. Compelling experimental tests of how effective wasps may be in biocontrol comes from Brazil, where *Polistes* paper wasps were shown to be effective in reducing the populations of FAW and sugar cane borers under semi-natural conditions. Brazilian researchers are also trialling the implementation of vespiaries in crop field, with the transfer of nests into specific locations to maximise their impact. Importantly, this approach would only consider augmenting populations of *native* social wasps, not introducing non-native species.

Diversity & abundance in Ghana/Nigeria. In contrast to Brazil, social wasps are little studied and thus poorly documented in Africa. Despite this, it is clear that social wasps are abundant and diverse in Ghana and Nigeria, and they can be found in abundance on houses, farm buildings, trees and other structures in rural areas. Local knowledge among farmers in recognising the wasps local to them is good; they also report seeing wasps in the fields. The use of social wasps as part of biocontrol programmes in small-holder farms in West Africa therefore is enormously promising, albeit so far unexploited.

4. Challenges in implementing biocontrol using natural enemies in Ghana: biological, cultural and logistical perspectives

This section outlines the key challenges posed in the use natural enemies as identified by the Network, through discussions and examination of the literature. It is not intended as a comprehensive review, but rather a representation of the Network's collective knowledge, opinions and expertise, as relevant to Ghanaian and Nigerian farming systems.

4.1 General Challenges

Societal and Cultural Challenges

Loss of traditional knowledge and culture. Historically, West African crop farmers have developed traditional methods for coping with crop pests, many of which have worked effectively. These include the application of wood ash or soil to the pests on the crop plants, or extractions from the neem tree (*Azadirachta indica)* – a non-native (naturalised) species which was introduced from Asia in the 19th century - which offers multipurpose treatments as a natural pesticide, fertilizer and source of traditional medicine (e.g. for treating malaria and intestinal worms). The seeds and leaves contain the chemical azadirachtin, which repels insects and affects their reproductive and digestive physiology. Traditional knowledge such as this is threatened by the 'technical comfort' offered by pesticides: farmers may no longer feel inclined to engage with traditional farming practices and knowledge, given that pesticides alone appear to deal with the issue with less effort. Additionally, the arrival of new crop pests such as FAW and changes in weather patterns due to climate change - with associated pest phenological shifts - now mean that traditional methods may be less effective. Over time these factors threaten the retention of traditional practices and local expert knowledge within communities. This constitutes a loss of culture and local knowledge: stories, traditions and practical uses such as medical treatments may be forgotten.

Training and knowledge transfer. Farmers can be resistant to adopting new technologies and approaches if they have poor perceptions of it, if they have not seen it in action, if the rest of the community is not on board and if the leader (e.g. village chief) is not supportive. Effective knowledge transfer with farmers can be challenging due to language barriers and the sparse availability of government employed extension officers, who are the primary source of advice and support for farmers; e.g. the community farm we visited in Ghana shared a single extension officer with over 100 other communities. Demonstration plots, effective knowledge transfer and strong community engagement with any new approach are essential. It is essential to remain sensitive to these issues as no change can be implemented if the farmers themselves are not enthusiastic.

Challenging perceptions. Long-standing cultural perceptions can also be a barrier to change, especially when the 'technology' being offered is unusual (e.g. promoting hunting wasps, which sting). The rapid changes in crop pests that farmers are encountering, due to climate change and species range expansions, mean that farmers have become hyper-cautious of *any* insect: farmers reported that they will kill any insect they see, without regard for whether it is a pest or beneficial insect. This is because they cannot be sure whether an insect presents a threat to their crops and livelihood. Tools to help farmers identify insects and their roles in farms and natural ecosystems could help.

Governmental and political challenges

Lack of incentives for pesticide-free produce. Efforts to implement farming practices that forego pesticides (e.g. agroecology or organic farming) are rare across Ghana as there is little market for such produce. These farming methods require more time and effort, yet the farmers are not recompensed for this, meaning that there is little incentive to not use pesticides. For instance, although neem oil (a natural repellent extracted from neem trees) is an effective pest repellent, it requires high labour costs.

Legislation and enforcement. Brazil now has legislation to promote biocontrol using fungi and parasitoids to reduce the use of pesticides. Currently, there is no such legislation in Ghana or Nigeria. Adoption of biopesticides (including parasitoid wasps and other more sustainable methods) would require government support; this could be through financial compensation to farmers if crops fail, initial investment to parasitoid producers, enforcement to ensure that commitments are being upheld, and investment in training of extension officers in these new technologies.

Political situation. In Ghana, there is potential for support from the government to establish more sustainable methods of pest control. The government (Ministry of Agriculture, MoFA) is aware that pesticides should be minimised to reduce the health and environmental impacts; however, there are currently few alternatives available. Policy is currently being renewed, so it is important to engage with MoFA as soon as possible to ensure that other possibilities are considered and promoted.

The political situation in Nigeria for biocontrol is more difficult to navigate. Although there have been initial releases of parasitoids by the IITA, the research community lacks the investment and opportunity to develop these technologies. It appears that it is difficult for Nigerian researchers to find funding; they report a lack of interest from the government in environmental matters. They do not believe that support can be expected in the same way in Nigeria as in Ghana.

4.2 Parasitoids - Specific Challenges

Local efficacy varies. A key challenge for any biocontrol programme lies in determining how effective a specific parasitoid will be for any one pest species. Parasitoids that are widely used worldwide are known to be efficient agents of biocontrol; however, efficacy can differ depending on the context. For instance, the influence of monocultures vs mixed cropping/agroforestry plots is little known: parasitoids are known to be efficient in monocultures, where they are exposed to one main prey species on the same crop, but they might struggle to find the pest in a more heterogenous system, or given a choice of hosts, the parasitoid may favour a non-target species over the pest species. A trial release of *T. remus* in Ghana found that the parasitoids dispersed into surrounding field, making it difficult to assess the impact of the release on pests. It is important to assess the efficacy and specificity of potential parasitoids in smallholder farms before releasing them on scale, to ensure that the efforts taken in population augmentation deliver the appropriate rewards in crop yields.

Unknown impacts on non-target species. The degree of host-specificity by a parasitoid can be difficult to determine, especially if it is not already a key part of the ecosystem. Host-switching can occur, resulting in spill-over effects on the surrounding natural ecosystem. Parasitism of non-target species can impact populations of essential pollinators and/or other natural enemies, with potential detrimental consequences on ecosystem function and local biodiversity. This risk applies whether the parasitoid is native or non-native, as the population augmentation of even a native species can alter the balance of an ecosystem.

Risks posed by non-native parasitoids. An outstanding question is whether the use of a non-native parasitoid should be encouraged at all. The best parasitoid for any one pest typically originate from the same native range as the pest. Since crop pests are often alien invasive species, this means that the best parasitoid for biocontrol will also be non-native. A prime example, of great relevance to Ghana and Nigeria, is *T. remus;* this parasitoid has exhibited high efficacy in controlling Fall Army Worm outbreaks around the world, including Brazil. *T. remus* originates from Southeast Asia but now occurs worldwide due to spread of hosts and introductions through IPM. *T. remus* is thought to be specific in its host choice, limiting its impact to *Spodoptera* species (of which FAW is a member). Despite this, and its wide-spread introduction and use, remarkably little (if anything) is known about the effects of *T. remus* on non-target native insect populations. It is important to understand which native lepidopteran species it can attack, as well as the impact on other competing natural enemies.

These risks must be properly considered. It is important for governments to have evidence-based legal procedures and risk assessments in place for any organism to be released. These risks are also some of the reasons why it is considered best to promote native species by providing suitable habitat, as the risk of unintended consequences caused by introduced natural enemies is lower. Weighing up the societal pros against the possible ecological cons of augmenting populations of non-native species remains a key challenge.

4.3 Social Wasps – Specific Challenges

Life-history knowledge gaps. Although promising, there has been little research into social wasps for biocontrol. Outstanding questions on some fundamental aspects of social wasp life-history and natural history require attention in order that social wasp populations can be effectively managed for pest control.

Efficacy in pest control. Although there is descriptive evidence from Brazil and West Africa that crop pests form part of the diet of native social wasps, and there is experimental evidence on the efficacy of social wasps on pest populations and crop damage under controlled conditions (in Brazil), field trials in natural settings are yet to be conducted. This is important not only for the scientific evidence base for assessing the economic impact of social wasps as biocontrol agents, but it is also important in providing demonstration plots of social wasps in action for local farmers to witness their potential.

Development of husbandry methods. The independent founding social wasps are relatively easy to handle, compared to the swarm found wasps, due to there being fewer wasps per nest. Their nests (with adults and brood) can be translocated to areas with crop pests, and away from areas of human habitation. In this respect, husbandry methods (including personal protective equipment and health and safety protocols) can be adapted from those used in handling and managing honeybees. However, little is known about variation in translocation success, including how local environment and previous diet/experience might influence the chance that re-located wasps will remain on their original nest rather than absconding and found a new nest elsewhere.

Public perceptions and attitudes. Social wasps have a bad reputation in many areas of the world largely due to their sting, hindering interest, research efforts and understanding. Perceptions across West Africa appear to be mixed: our experience in southern Ghana revealed that wasps are mostly despised and that their nests are frequently destroyed; conversely in other parts of Africa social wasps hold some cultural and social value as protectors of people’s homes. It is essential to work with communities to understand their attitudes to provide targeted education and training on their benefits and ways to handle them to change to encourage farmers to use these wasps.

5. Opportunities for Collaboration & Key Stakeholders

We have identified two key areas as potential opportunities for collaboration, which could be developed separately or jointly as complementary approaches to nature-based solutions for integrated pest management in small-holder farmers.

5.1 Upscaling Parasitoid Production as Biocontrol for Small-holder Farmers

A clear outcome from this Scoping Project is that there is the need and desire from end-users, and the expertise, technology-base, business model and ambition among stakeholders to explore the possibility of scaling-up parasitoid production as a business or social enterprise in Ghana.

Network members from Brazil (academia and industry) have evidenced the success of large-scale production of parasitoids for control of crop pests, including FAW. Parasitoids can be farmed on-scale, in numbers that can have equivalent impacts on pest populations and crop yields as do pesticides (on pre-resistant pests). Network members from Ghana and Nigeria (academia, research institutes and government) have expertise in parasitoid rearing, but at a smaller scale due to the limitations in funding and infrastructure. Their success in small-scale releases of parasitoids in small-holder farming communities provides essential information on local conditions for up-scaling the rearing of parasitoids in Ghana, in deploying them to the farms and for knowledge transfer and dissemination to ensure farmers are receptive and the parasitoids are used correctly at the right time.

Successful up-scaling in Ghana, where there is government support and opportunity for policy change, would then hopefully provide a successful roadmap for replication in Nigeria and other African countries, where there is support from the academic and research community but less so from government. This could also include diversifying the rearing portfolio to include other parasitioids, such that the use of native parasitoids could eventually be favoured over the introduction of non-native species. However, it is important to note that local engagement with individual target communities is essential, well in advance of any in-field deployment, in order to tailor appropriate modes and levels of knowledge transfer and training in ways that work best with local cultural diversity. Thus, although up-scaling technology of the parasitoid production may be relatively generic, local-scale implementation is unlikely to be so.

Fig 1: Large-scale parasitoid production in Brazil.

5.2 Developing Social Wasps as Biocontrol Agents for Small-holder Farmers

The idea of using social wasps as biocontrol was a harder sell than the parasitoids. This is unsurprising given that these wasps often have painful stings and as a result people are reluctant to tolerate them. However, both potential end-users and stakeholders expressed curiosity in the idea when the evidence of their effectiveness as biocontrol of FAW, sugar cane borer and other Lepidopteran pests was explained. Enthusiasm was, however, patchy. It is clear that demonstration of evidence base and safe handling techniques for these insects is required before they can be implemented on a commercial scale. The fundamental skills and base-line data is, however, sufficiently compelling that further research in this area is very much desired and encouraged.

5.3 Community Engagement Opportunities for Nature-Based Agricultural Innovation

All sectors of the Network recognised the importance of community engagement, communication, knowledge transfer and training of farmers in any farming initiative. Although this is ostensibly the role of government employed extension officers, there are clearly not enough government officers to provide the support communities need. This is especially the case with the arrival of new, devastating pests (e.g. FAW) which both farmers and extension officers lack experience in managing; and the increasing unpredictability of the weather due to climate change, which means that traditional farming knowledge of farmers – and the training given to extension officers - is sometimes no longer relevant. Farmers are open to new ideas if they have been provided with convincing evidence (e.g. demonstration plots) that the new approach will work. However, concerns about how closely protocols for application are followed were expressed by officials, as well as how well farmers were able to understand written instructions if they are not in their tribal language. Any programme seeking to promote parasitoid wasps or social wasps as biocontrol in community farms will require close and continued engagement with farmers, ensuring there are trained and supported to ensure success.

<u>One such example is</u> Wild Rain - a registered organisation, based in the Akwamu-Kwanyarko community in Eastern Ghana; this organisation is helping the farmers in the community to transition from the heavy reliance on agrochemicals to natural and organically produced pesticides like the neem extract. The farmers are all individual smallholders, with each only farming at most a few acres each across which a variety of crops is grown. Most of this produce is for their own subsistence, but any surplus is sold at market.

Crop pests such as FAW are a major issue here. The farmers are becoming increasingly desperate to find solutions to increased environmental pressures - including climate change and pests. They are aware that pesticides can have detrimental impacts to their health and are eager to find alternative solutions. However, there is a major challenge to overcome regarding communication: they told us that support and engagement from government and extension officers are lacking, contributing to failure in adequate crop protection.

Wild Rain are implementing an agroforesty approach, improving soil and reducing reliance on pesticides. A pilot demonstration plot run by Wild Rain showed that in the absence of pesticides, maize grown on improved soil, with other plants intercropped, yielded substantially more produce than adjacent fields where maize is treated with pesticides. This small demonstration serves as a tool to prove to farmers that agroforestry, no-chemical methods of farming can be very effective. Bringing the community on side opens up opportunities for other nature-based approaches of farming to be trialled and introduced; e.g. using natural enemies.

Fig 2: Farmers of the Kwanyarko community

5.4 Business Models for Nature-Based Agricultural Innovation

Commericalisation. Alongside community engagement, another key ingredient for success in either of the suggested ventures is the interest and commitment of local businesses with the skills and appetite for insect rearing and nature-based agricultural solutions. We came across once such example in Ghana which specialises in a circular economy of rearing Black Soldier Fly (BSF) from recycled organic waste. These flies produce organic fertilisers for agriculture but can also be sold as food for animals, such as fish. Working with insect farming companies like this to diversify portfolios may be promising.

Social Enterprise. As well as selling BSF-generated feed and fertiliser to farmers, they also run a social enterprise model that serves to decentralise production of BSF to the farmers themselves. Farmers can choose to be trained in the skills and set up required to rear the flies themselves, such that they can set up community-led BSF farms, producing their own animal feed and fertilisers using their own agricultural organic waste. This model of social enterprise that promotes self-sufficiency and a zero-waste circular economy is really exciting, giving autonomy to farmers and releasing them from reliance on (less sustainable) products from global agroindustry.

Although not involving insects, a second relevant example of social enterprise and farmer autonomy is a community-run mushroom farm in Eastern Ghana, set up by WildRain. This farm is physically based in the Kwanyarko community and it produces oyster mushrooms that can be sold to food outlets in Accra (~2.5h away). Importantly, this mushroom farm mostly employs single mothers. Teenage pregnancy is a big issue in Ghana, and this often causes young women to fall out of education and subsequently to miss out on employment opportunities. The women are paid for their work but can also buy the mushrooms at a set price to then sell for a markup. Given that female workers dominate the work force in the Brazilian wasp factories because they have proved especially effective in insect rearing, the precedent of a female-worker force provided by the Wild Rain Mushroom farm is extremely promising.

Fig 3: Oyster mushroom farm at Kwanyarko community farm provides employment and income for single mothers.

6. Gender and Social Inequality

We highlight some of the inequality issues that came to light within our Network and from our in-country visits and meetings.

Health risks from agrochemicals. Studies in other parts of Africa have already highlighted the inequalities in exposure risk to toxic agrichemicals with respect to gender. We were told that in Ghana the role of women in agriculture and social structures varied across communities; however, in many communities the farmers who are most likely to be tending the fields are women, often accompanied by small children. As a result, they are more exposed to agrochemicals than men. Farmers rarely have access to (or can afford) personal protective equipment (or they do not use it properly) and so exposure to toxicity is a real risk. This may be further confounded by the fact that women often have poorer access to resources than men and thus may be even less likely to have access to appropriate PPE.

Education and Teenage Pregnancy. Children might expect 12 years of school education in Ghana and 10 in Nigeria. Prior to 2010, girls in Ghana were less likely to finish lower secondary school (age 14) than boys; since 2010, gender parity is largely being achieved. In Nigeria the data are less good: girls are consistently less likely to finish school than boys. One reason for the lower completion rates for girls than boys is teenage pregnancies; sub-Saharan Africa has the highest rates of teenage pregnancy in the world and Ghana (7% of pregnancies) and Nigeria (10% of pregnancies) are no exceptions. Teenage pregnancies result in girls dropping out of education. Level of education impacts farming practice. For example, farmers with higher levels of education were more willing to pay for biopesticides than those with no education, and were more likely to produce food to sell rather than just for personal consumption. Level of education also influences propensity to use of PPE (or use it properly) as well as receptivity to training and adoption of new methods. Men in Ghana were more likely to have read and understood the impacts of pesticides on health than women.

Decision-making rights and access to information. Despite their central role in agriculture, women often lack rights and opportunities, such as land-ownership, control over decision making and access to resources, agricultural support services, financial advice and services. This might include meetings with extension officers, or their access to online resources because they may be less likely to have access to a mobile phone; if they do have access it may not necessarily be a smart phone. Hence, many of the resources and technology (e.g. apps) that are being developed for African farmers are not always equally available to women as they are to men. Women may also miss out on key information transfer opportunities as they are more likely to be taking produce to market to sell than men are. A recent cross-sectional study in Ghana highlighted the importance of age with a woman's status: older women are more likely to be involved in agricultural decision making. We observed these power imbalances in Ghana, where at our consultation with farmers men far out-numbered women, because the women had gone to market; the women who were present were mature.

***Climate-smart agriculture and opportunities for women**.* Any future ventures, therefore, must adopt a gender-responsive approach to ensure that men and women can benefit equally. Failure to do this could mean that the implementation of CSA approaches simply reinforce and possibly widen existing inequalities. Opportunities like the Kwanyarko community mushroom farm, which provides employment for single teenage mothers who have left school early, is a model of success. Moreover, the Brazilian parasitoid factories employ a largely female work force (including at the management level); this also sets a precedent model for empowering women in the implementation of CSA approaches.

7. Barriers to transformational change

We use the hypothetical CSA innovation of large-scale parasitoid production in Ghana for small-holder farmers as an exemplar model to address the barriers to transformational change, as the foundations are in place and ready for the implementation of change.

1) Evidence of effectiveness: have technologies/ services proven successful in another location, how lessons could be shared?

- Parasitoid technologies are used to control pests around the world, particularly in extensive agriculture, and are government-endorsed in some countries, e.g. Brazil. Some of the largest agricultural producers in the world are rearing parasitoids in-house to serve as biocontrol.
- Brazilian parasitoid producers have now amassed a great deal of expertise over multiple decades. They are therefore very well placed to provide technical assistance and commercial know-how to West African producers to upscale production for large-scale distribution.

Limitations:

- Although parasitoids are being reared on small scale in government offices, upscaling of these technologies has not been trialled in Ghana or Nigeria; moreover details on the implementation and success of releases in West Africa are hard to ascertain.
- Parasitoid technologies alone are unlikely to be sufficient to control pests: they should be used in combination with other pest control methods (traditional farming methods, low levels of synthetic pesticides during severe outbreaks, other biopesticides such as neem, use of other natural enemies like social wasps).
- Parasitoids are less readily available for smallholder farmers in areas of mixed cropping: therefore, the efficacy of parasitoids in smaller, more heterogenous landscapes is less well known. Controlled releases and subsequent monitoring is required and appropriate risk assessments must be completed.

2) Capacity and capability: What is needed to make change, and to what extent does the capacity and capability for change exists?

- Ghana already has a small rearing facility in Accra at the Ministry of Agriculture that has been used successfully to release parasitoids at small scales on a few farms, under the model of a social good as opposed to any plans to monetise. Collaboration with this department will accelerate the process, will facilitate communication with the government, and possibly provide opportunities to influence policy.
- There are various organisations across West Africa that are experienced in rearing parasitoids and/or in communicating with farmers and rolling out technologies across the country. These organisations should be consulted to facilitate technology development and gender-responsive community engagement and training/
- There are also some small circular-economy, insect-farming companies in West Africa, for example rearing Black Soldier Fly. These have high capability to expand production and commercialisation of parasitoids given their prior experience with insect rearing and engagement with farmers.
- Communication with farmers is essential. Pre-existing channels would be suitable for such outreach such as extension services and Farmer Field Schools; however, this would require commitment from government.

3) **Innovation:** ***What innovation is required for change, at which stage of innovation, what are the barriers/ challenges associated with innovation?***

Parasitoid rearing at scale is highly feasible and is low risk due to the model and technology development by factories in Brazil. Innovations include:

- The parasitoid rearing process is a relatively simple process but requires specific technical expertise, infrastructure and training. This will require significant initial investment and education.
- Distribution may be one of the main limiting factors across Ghana: there is scope to decentralise production; however, this will require significant investment and research to determine the feasibility. This may be one area with most scope for innovation: creation of small scale, yet streamlined production facilities so that communities can rear their own parasitoids for release.
- Some experimentation early in the process to fine-tune suitable protocols for mass rearing will be essential. These protocols may be sought from other producers if they are willing to share their expertise.
- Demonstration plots will be necessary to test the parasitoids and show farmers how they can be used.

8. Key Reading

Agboyi, Lakpo Koku, Babatoundé Ferdinand Rodolphe Layodé, Ken Okwae Fening, Patrick Beseh, Victor Attuquaye Clottey, Roger Day, Marc Kenis, and Dirk Babendreier. 'Assessing the Potential of Inoculative Field Releases of Telenomus Remus to Control Spodoptera Frugiperda in Ghana'. *Insects* 12, no. 8 (22 July 2021): 665. https://doi.org/10.3390/insects12080665.

Agboyi, Lakpo Koku, Georg Goergen, Patrick Beseh, Samuel Adjei Mensah, Victor Attuquaye Clottey, Raymond Glikpo, Alan Buddie, et al. 'Parasitoid Complex of Fall Armyworm, Spodoptera Frugiperda, in Ghana and Benin'. *Insects* 11, no. 2 (21 January 2020): 68. https://doi.org/10.3390/insects11020068.

Brock, Ryan. E., Alessandro Cini, and Seirian Sumner. 'Ecosystem Services Provided by Aculeate Wasps'. *Biological Reviews* 96, no. 4 (2021): 1645–75. https://doi.org/10.1111/brv.12719.

Bueno, R.C.O.D.F., Carneiro, T.R., Pratissoli, D., Bueno, A.D.F. and Fernandes, O.A., 2008. Biology and thermal requirements of *Telenomus remus* reared on fall armyworm Spodoptera frugiperda eggs. *Ciência Rural*, *38*, pp.1-6.

Colmenarez, Y.C., Babendreier, D., Ferrer Wurst, F.R., Vásquez-Freytez, C.L. and Bueno, A.F., 2022. The use of *Telenomus remus* (Nixon, 1937)(Hymenoptera: Scelionidae) in the management of *Spodoptera* spp.: potential, challenges and major benefits. CABI Agriculture and Bioscience, 3(1), p.5. https://doi.org/10.1186/s43170-021-00071-6.

Driesche, R. Van, and M. Hoddle. 'Non-target effects of insect biocontrol agents and trends in host specificity since 1985.' *CABI Reviews*, 5 April 2017, 1–66. https://doi.org/10.1079/PAVSNNR201611044.

Ministry of Food and Agriculture Report. (2022) Integrated Pest Management Plan (IPMP) West Africa Food System Resilience Programme, Republic of Ghana. https://projects.worldbank.org/en/projects-operations/project-detail/P178132

Naranjo-Guevara, N., Santos, L.A.O., Barbosa, N.C.C.P., Castro, A.C.M.C. and Fernandes, O.A., 2020. Long-term mass rearing impacts performance of the egg parasitoid Telenomus remus (Hymenoptera: Platygastridae). *Journal of Entomological Science*, 55(1), pp.69-86.

Nelson S. & Huyer S. 2016 Taking a Gender-Responsive Approach to Climate-Smart Agriculture (CSA). FAO Practice Brief.

Pomari-Fernandes, A., de Freitas Bueno, A., De Bortoli, S.A. and Favetti, B.M., 2018. Dispersal capacity of the egg parasitoid Telenomus remus Nixon (Hymenoptera: Platygastridae) in maize and soybean crops. *Biological Control*, *126*, pp.158-168.

Prezoto, Maciel, Detoni, Mayorquin, and Barbosa. 'Pest Control Potential of Social Wasps in Small Farms and Urban Gardens'. *Insects* 10, no. 7 (2019): 192. https://doi.org/10.3390/insects10070192.

Southon, Robin J, A. Fernandes, Odair, Fábio S. Nascimento, and Seirian Sumner. 'Social Wasps Are Effective Biocontrol Agents of Key Lepidopteran Crop-Pests'. *Proceedings of the Royal Society B Royal* 286, no. 1914 (2019): 20191676. http://dx.doi.org/10.1098/rspb.2019.1676.